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Impact of Primary Sulfate and Nitrate Emissions from Selected Major Sources Phase 2: Sulfuric Acid Plant and Pulp and Paper Mill

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IMPACT OF PRIMARY SULFATE AND NITRATE EMISSIONS FROM SELECTED MAJOR SOURCES

Phase II: Sulfuric Acid Plant and Pulp and Paper Mill

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16. ABSTRACT

This report covers Phase two of a two phase study of the near source impacts of primary sulfate and nitrate emission sources. The phase two portion of the study was an investigation of the impact of the emissions from a sulfuric acid plant, and a pulp and paper mill. The study was designed to measure the increases in the ground-level ambient air sulfate and nitrate concentrations resulting from the plant's emission within ten kilometers of the plants. The field sampling involved concurrent sampling at the source and in the ambient upwind and downwind of the plants for particulate matter, sulfates, nitrates, sulfuric acid, nitric acid, SO_2, and NO_x.

The tests were conducted in Savannah, Georgia and were centered around a sulfuric acid plant operated by American Cyanamid; Inc., and a pulp and paper mill operated by the Union Camp Corporation. Both plants operated at full capacity throughout the tests

The Factor analyses based on elemental analyses of the ambient air particulate samples, the plants emission and local soil samples indicated that wind blown soil was the dominant source of ambient particulate matter. The target sources were responsible for only a small fraction of sulfate and nitrates. The major source appeared to be secondary aerosols, perhaps dominated by long-range transport.

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ABSTRACT

This report covers Phase II of a two-phase study of the near source impacts of primary sulfate and nitrate emission sources. The Phase I portion of the study was an investigation of the impact of a coal-fired power plant burning a high-sulfur coal. The Phase II portion of the study was an investigation of the impacts of a pulp and paper mill, a sulfuric acid plant, and an oil-fired power plant. The study was designed to measure the increases in the ground-level ambient air sulfate and nitrate concentrations within ten kilometers of the plants resulting from the plants' emissions. The field sampling portion of Phase II was carried out during August of 1981.

The field sampling involved concurrent sampling at the sources and in the ambient upwind and downwind of the plants for particulates, sulfates, nitrates, sulfuric acid, nitric acid, SO_2, and NO_x.

The tests were conducted in Savannah, Georgia and were centered around a sulfuric acid plant operated by American Cyanamid, Inc. and a pulp and paper mill operated by the Union Camp Corporation. The American Cyanamid sulfuric acid plant operated at its full capacity of 750 tons per day throughout the tests. The Union Camp pulp and paper mill has a pulp capacity of 2850 tons per day of which 2550 tons per day are produced by the Kraft process. The plant includes three each recovery boilers, lime kilns, and power boilers; all of which operated at full capacity throughout the test period with the exception of a few short term outages. The oil fired power plants which were intended to be included in the study were captive plants operated by the Union Camp Corporation and a power station operated by Savannah Gas and Electric Company. The availability of natural gas as a fuel source during the test period resulted in no fuel oil being used for firing the power boilers during the tests.

The average concentration of TSP in the ambient was about 120 $\mu g/m^3$ while the average sulfate and nitrate concentrations were respectively 6 $\mu g/m^3$ and 2 $\mu g/m^3$. Factor analysis based on elemental analyses of ambient air particulate samples, the plants' particulate emissions, and local soil samples indicated that wind blown soil was the dominant source of the ambient particulate matter. Factor analysis, dispersion modeling, and comparative upwind-downwind concentrations indicated that primary sulfate and nitrate emissions from the target sources were responsible for only a small fraction of the observed ambient concentrations of these materials. The major source of the observed sulfates and nitrates appeared to be secondary aerosols, perhaps dominated by long-range transport.

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SECTION 1

INTRODUCTION

This report covers the work performed in the second phase of a two phase study entitled "Assessment of the Impacts of Primary Sulfate and Nitrate Emissions on Air Quality in the Vicinity of Industrial Plants". The Phase 1 study was concerned with the impact of a coal-fired power plant and is reported separately. The phase two study was concerned with the impacts of a sulfuric acid plant and a pulp mill.

The study was conducted as a joint research project of Southern Research Institute (SoRI) and TRC Environmental Consultants (TRC) with TRC serving as a subcontractor to SoRI. Source emissions data, together with the measurement of ambient particulate elemental composition by particle size, and ambient sulfuric acid concentrations were the responsibility of SoRI. TRC was responsible for obtaining ambient data concerning meteorology, total suspended particulate concentrations, nitrate and nitric acid, and the gaseous species SO_2, NO, and NO_2. The phase two study was conducted during August, 1981 in Savannah, GA. The emission sources on which the study was centered were an acid plant operated by American Cyanamid, Inc. and a pulp and paper plant operated by The Union Camp Corporation.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

Neither of the plants around which the Phase II study was based were found to be major contributors of sulfates, nitrates, SO_2, or NO_x to the local environment. In fact, no direct linkage of any portion of the measured local ambient sulfate and nitrate concentrations with the target sources could be made on the basis of the data obtained during this test.

Factor analysis combined with meteorological data indicated that the dominant sources of sulfates and nitrates in the local environment were the results of long-range transport and/or secondary aerosol formation. These analyses failed to show any direct impact of the sources in question in terms of sulfates, nitrates, or total particulate concentrations - target transformation factor analysis of the ambient data base produced negative results for either individual sources, source classes, or total emissions for each of the two plant sites. (14 sources in four classes at the pulp and paper site and three sources in two classes at the acid plant site.)

Dispersion model predictions of downwind sulfate concentrations resulting from the sulfuric acid plant emissions resulted in values no larger than 0.2 to 0.5 $\mu g/m^3$ while the observed upwind and downwind concentrations were in the range of 1 to 15 $\mu g/m^3$. Peak concentrations for the acid plant were predicted to occur at distances of about 1km.

Dispersion modeling of downwind sulfate concentrations resulting from the pulp and paper plant emissions predicted peak values between 4 and 9 $\mu g/m^3$ at distances between 0.5 and 0.8km. At distances between 2 and 10km, within which most of the ambient data were collected, the predicted concentrations ranged up to about 2 $\mu g/m^3$, while the measured concentrations upwind and downwind of the plant ranged from about 3 to 30 $\mu g/m^3$. Typically the concentrations predicted by the dispersion model ranged from 1 to 10 percent of the measured values. Similarly, the dispersion model predictions of NO_x concentrations downwind of the pulp and paper plant were 1 to 10 percent of the measured values. The primary sources of NO_x at pulp and paper plant were the power boilers, while the primary sulfate sources were the recovery boilers.

The greatest ambient sulfate concentrations measured during the test program occured on days when the atmosphere was quite hazy throughout the region. These high sulfate levels were probably secondary in origin and a result of long range transport. Back trajectory calculations of air mass movements for the periods in question might be useful in identifying the probable origin of the sulfates observed during these episodes.

Diurnal variations in the ambient NO_x concentrations suggested that automotive sources were the primary source of that pollutant within the study area.

SECTION 3

BACKGROUND

The development of prudent emissions control strategies on both local and national scales requires characterization of the numerous pathways taken through the atmosphere by gases and particulate matter from sources to eventual receptors. Gases emitted into the atmosphere disperse and react directly with receptors at ground level or are converted to particulate matter through gas phase reactions or through reactions with pre-existing particles (including adsorption). Aerosol particles tend to grow in size through reactions with gases and by agglomeration. Particulate matter leaves the atmosphere through turbulent diffusion (or dispersion), precipitation, and settling.

Sulfur and nitrogen compounds are of particular concern because of their preponderance in combustion flue gases and in decomposition products of other process streams. High levels of SO_2, NO, NO_2, and various sulfates and nitrates are found in ambient air associated with industrial activity and areas with high automotive traffic densities.[1-12] Serious deterioration of the environment has been linked with these compounds.[13-17] The dangers of sulfur emissions have been suspected for centuries.[18] In 1964 SO_2 emissions began to be regulated in this country. The use of high sulfur fuels was inhibited and taller stacks were employed to improve local air quality. This improved the measured levels of SO_2. However, ambient sulfate levels have not been substantially improved. Furthermore, correlation studies of respiratory infections with SO_2 and the sulfate levels have linked health problems to sulfate levels more directly than to SO_2 levels.[17] Thus it is important that the specific contributions of these aerosols to the atmosphere be delineated, the controlling mechanisms be determined, and the local and long range concentrations and transport be measured.

Much research work in recent years has dealt with this problem. Numerous mechanisms have been identified as a result of source and ambient measurements. However, the relative importance of the mechanisms are not understood because they are apparently dependent upon geographical location, meteorological conditions, and the specific nature of the sources.

Research and analysis of air quality treats aerosols as two types because of practical reasons related to measurement and the basic differences in the physical and chemical natures of process streams and ambient air. A primary aerosol is the particulate matter exiting the source, including pre-existing vapors such as sulfuric acid which become supersaturated and condense in the near source plume. A secondary aerosol is that formed by gas-to-particle conversion due to a chemical reaction. Practically speaking, a secondary aerosol has been considered as that formed over long periods in the ambient air and measurable at great distances from the sources. However, significant oxidation of SO_2 to particulate sulfate is sometimes found in the vicinity of sources.[20-26] Indications of such oxidation in a power plant plume was found during phase one of this program.

One of the important questions to be addressed in this project was whether increased primary aerosol or secondary aerosol formation is responsible for the higher sulfate/SO_2 ratios observed now in the atmosphere relative to a decade ago. For example, the use of taller stacks in recent years may have increased the residence time in the atmosphere causing greater oxidation of SO_2 to sulfate. On the other hand, the shift from high sulfur to low sulfur fuels such as oil may be the important factor due to higher concentrations of catalytic agents such as vanadium in the current fuels. It has been verified that fuel components other than sulfur and nitrogen are important in primary sulfate formation. For instance, sulfate levels emitted by oil-fired power plants are typically five-fold greater than those of coal-fired plants with equivalent sulfur contents.[19,20,21,26,27]

The sulfur content of fuels plays an important role in both primary and secondary aerosols. Most of the sulfur leaves the combustion process as SO_2; however, sufficient further oxidation occurs that sulfate is frequently the major component of the primary aerosol. No convincing evidence is known for significant nitrate formation in the combustion streams. N_2 in the combustion air and nitrogen in the fuel are oxidized to NO and NO_2, the latter comprising less than 10% of the total NO_x. These nitrogen compounds are of concern because of nitrate formation in the atmosphere and associated health[17] and acidification problems.

Most current studies on the mechanisms of sulfate and nitrate formation and transport in the atmosphere have dealt with, or are addressing the problems of long range transport. However, a significant portion of the problems associated with these compounds may arise in the near source vicinity. The program described here was intended to investigate several facets of this near source portion of the problem.

SECTION 4

PROGRAM DESCRIPTION

STUDY AREA

This study was carried out in and around the city of Savannah, GA. Savannah is a coastal city located on the Georgia - South Carolina border on the Savannah River about 25 km inland from the Atlantic Ocean. The city of Savannah occupies an area of about 65 sq. km (26 sq. mi.) and has a population of 118,350 (metropolitan area -188,000). The city is located on a coastal plain with no major elevation changes within the area. There are no metropolitan centers of similar or larger size closer than 120 km of Savannah. The location of the city is shown in Figure 1.

There are 155 manufacturing industries in the area, the major ones being pulp and paper, food, chemical, petroleum, shipbuilding, and lumber and wood products. The heavy manufacturing industries are located in a generally east-west line along the Savannah River. American Cyanamid's facility is located at the eastern extreme of the industrial development, about 19 km (12 mi.) inland from the ocean; Union Camp is located about 29 km (18 mi.) inland from the ocean, with the Savannah central business district located about halfway between the two. The industrialized area extends another 8 km (5 mi.) westward from Union Camp. The industrial and urban developments are confined wholly to the south side of the Savannah River. Figure 2 illustrates the locations of the two facilities around which the sampling was centered and identifies other potentially significant sources that lie within area encompassed by the study.

Two sulfuric acid plants were in operation in the area in addition to the American Cyanamid facility; one of these has a rated capacity of about 10 percent of that of Cyanamid and the other a capacity of about half that of Cyanamid. Both are parts of fertilizer manufacturing plants. In addition to Union Camp, several pulp mills operate in the area, only one of which uses the Kraft process - that being a plant with about one quarter the capacity of Union Camp, located at the western end of the industrial development.

TARGET SOURCES

The intent of the test program as originally planned was to quantify the impacts of three classes of primary sulfate emission

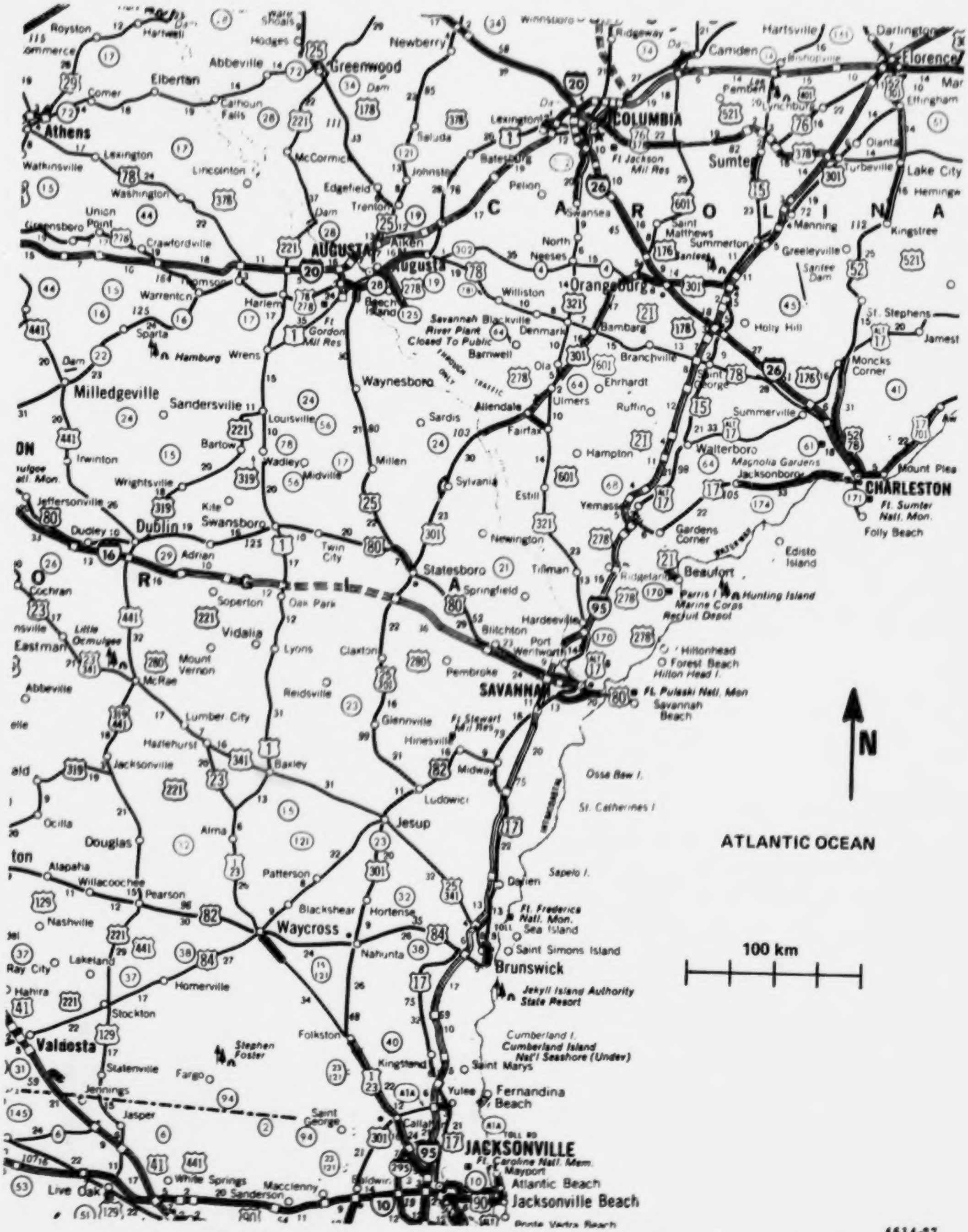
ATLANTIC OCEAN
N
100 km
SAVANNAH
CHARLESTON
COLUMBIA
AUGUSTA
JACKSONVILLE
Athens
Greenwood
Florence
Sumter
Orangeburg
Aiken
Milledgeville
Dublin
Statesboro
Waycross
Brunswick
Valdosta
Beaufort
Jesup
Vidalia
Waynesboro
Sylvania
Walterboro
Fernandina Beach
Jacksonville Beach
Savannah River Plant Closed To Public
Ft. Pulaski Nat'l. Mon
Savannah Beach
Ft. Stewart Mil Res
Ft. Gordon Mil Res
Ft. Jackson Mil Res
Hilton Head I.
Ossa Baw I.
St. Catherines I
Sapelo I.
Cumberland I.
Cumberland Island Nat'l Seashore (Undev)
Jekyll Island Authority State Resort
Saint Simons Island
Sea Island
Ft. Frederica Natl. Mon.
Parris I. Marine Corps Recruit Depot
Hunting Island
Ft. Sumter Natl. Mon.
Folly Beach
C A R O L I N A
G E O R G I A

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Figure 1. Map showing Savannah and surroundings to distances of approximately 400 km.

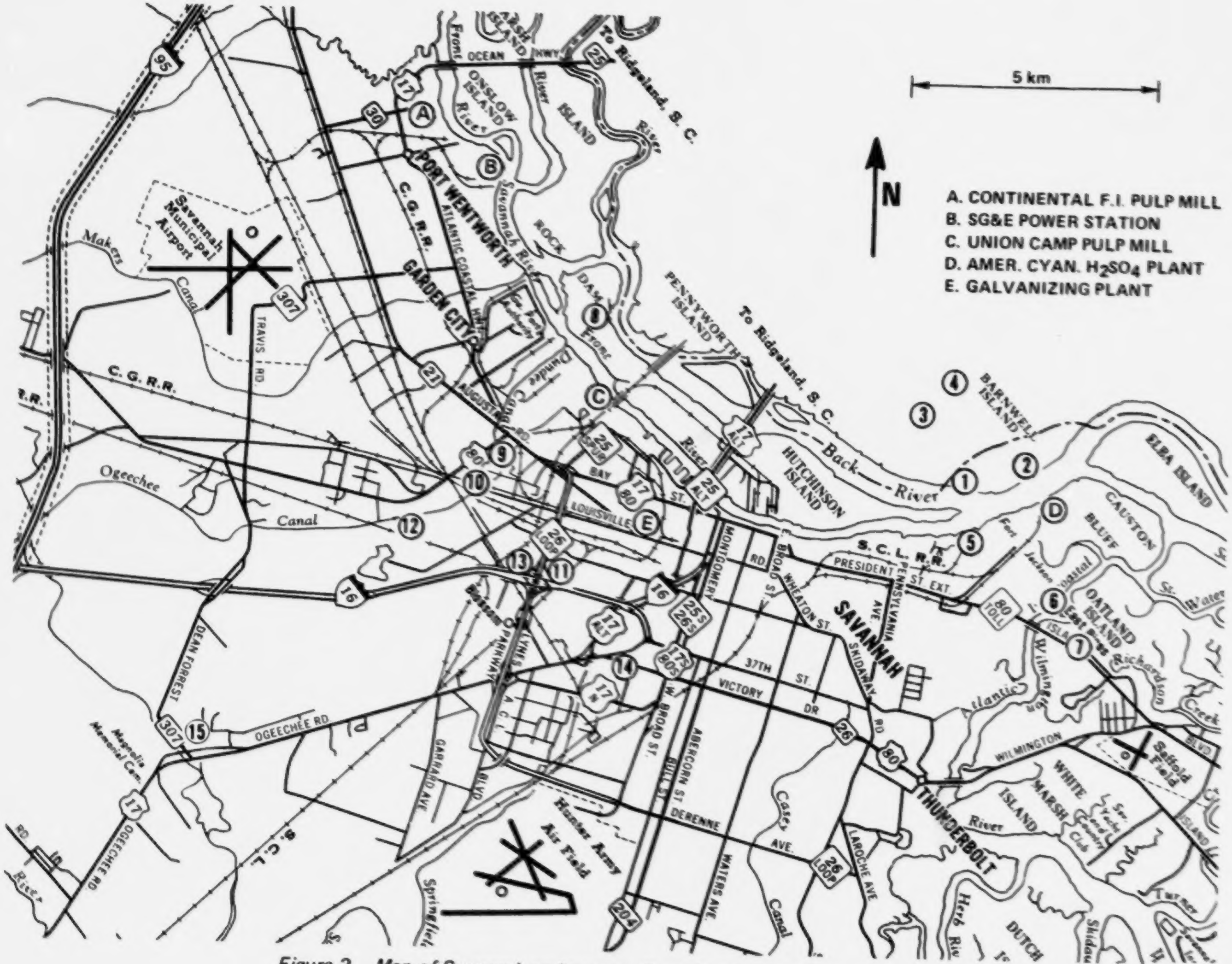

5 km
N
A. CONTINENTAL F.I. PULP MILL
B. SG&E POWER STATION
C. UNION CAMP PULP MILL
D. AMER. CYAN. H_2SO_4 PLANT
E. GALVANIZING PLANT
SAVANNAH
PORT WENTWORTH
GARDEN CITY
THUNDERBOLT
HUTCHINSON ISLAND
PENNYWORTH ISLAND
BARNWELL ISLAND
ELBA ISLAND
CAUSTON BLUFF
OATLAND ISLAND
ONSLOW ISLAND
WHITE MARSH ISLAND
Savannah Municipal Airport
Hunter Army Air Field
Saffold Field
To Ridgeland, S. C.
Back River
Savannah River
Ogeechee Canal
S. C. L. R.R.
C. G. R.R.
Magnolia Memorial Cem.
4614-28

Figure 2. Map of Savannah and surroundings showing locations cf significant sources and ambient sampling sites.

sources, a pulp and paper plant, a sulfuric acid plant, and an oil fired power plant, all of which were to lie in close proximity to one another. Savannah was one of a handful of locations having the specified combination of industries. The target sources in Savannah were the American Cyanamid acid plant, the Union Camp pulp and paper plant together with Union Camp captive oil-fired power boilers, and the Savannah Gas and Electric Company's Port Wentworth power plant. At the time the tests were scheduled the power boilers at both the pulp and paper plant and the utility were being fired with fuel oil; however, during the period when the tests were carried out, natural gas was available as a fuel source, and oil was not in use. Therefore the target sources were reduced to only the pulp and paper and acid plants.

Acid Plant

The acid plant operated by Cyanamid has a capacity of 750 tons per day and was running at capacity during these tests. The plant is a contact process type using water coolers followed by a Union Carbide Peterson scrubber for product collection and emission control. The acid manufactured by the plant is used on-site for digesting titanium ore for processing in a titanium dioxide plant. After use, the spent acid is conveyed to an on-site neutralization plant where it is reacted to form gypsum.

Three other potentially important sulfate sources are parts of the Cyanamid complex. There are some continuous sulfuric acid emissions associated with the ore digesters, but these are normally small compared to the emissions from the acid plant. However, on occasion, pressure surges in the digesters open emergency relief vents, at which times short-duration, high-concentration releases of sulfuric acid aerosol occur. Finally, the two calciners in which the digester products are converted to titanium dioxide represent additional possible sulfate sources. Scrubbers are used for controlling the digester emissions, while wet electrostatic precipitators followed by Peterson scrubbers are used for controlling the calciner emissions.

Emissions measurements were made at the acid plant and on each of the two calciners. Because of the extreme hazards involved, no sampling is ever permitted around the digesters. (Permit approval for the digester operations is made on the basis of calculated maximum possible emission rates.)

Pulp and paper plant

The Savannah plant of the Union Camp Corporation is the world's largest pulp and paper plant, with a pulp capacity of 2850 tons per day, of which 2550 tons per day are produced by the Kraft process. The major emission sources within the complex are three each recovery boilers, lime kilns, and power boilers. The recovery boilers have a rated capacity of 3000 tons per day; the lime kilns a capacity of 525 tons per day, and the power boilers a capacity of 2.045 million pounds of steam per hour. The power boilers are fired by 100 tons per day of bark and wood waste and 4655 gallons per day of fuel oil or the equivalent thereof.

Electrostatic precipitators are used for controlling the emissions from the recovery boiler flue gases, with scrubbers controlling emissions from smelt tank vents. Scrubbers are also used for controlling emissions from the lime kilns. One of the power boilers is fired exclusively by oil or natural gas (gas during these tests) and utilized no emission control equipment. The remaining two power boilers are fueled by bark and wood waste with oil or gas as a supplementary fuel (gas during these tests). One of these uses only mechanical collectors, while the second uses a Combustion Power gravel-bed filter for emission control. The flue gases from both of the bark fired boilers are discharged through a common stack.

Characterization of the Union Camp emissions required sampling from fourteen points of discharge; three stacks associated with each recovery boiler, one from each lime kiln, and two associated with the power boilers.

PARAMETERS OF INTEREST

The primary variables of interest in this study were of course, particulate and gaseous sulfates and nitrates in the ambient air which were directly the result of emissions from the Union Camp and Cyanamid facilities. Further, it was desirable to differentiate between sulfate and nitrate salts, and sulfuric and nitric acid. Thus data were needed on the ambient and source concentrations of these variables and their precursors.

In order to separate the contribution of the target sources from those of other sources, knowledge of the background concentrations of the target variables was required together with the identification of other potential contributors. The species of interest are reactive and are probably not conserved, even over the short transport distances involved in this study. Therefore, other tracers of the plants' emissions were desired, from which dilution factors might be obtained for the plumes downwind of the plants. Signatures based on the emission rates of a number of chemical elements in the particulate matter emitted by each source were selected for this purpose. Because particle deposition rates are size dependent, the emission signature to be used was one in which the composition of the particulate matter was separately determined for a number of size classes. By doing this, the coarser particles, which are depleted more rapidly in a plume, could be discounted in the tracer analyses.

The final test matrix included the measurement of the following in the sources and ambient, respectively. In the case of a source, measurements were made of the emission rates of sulfuric acid, sulfate salts, sulfur dioxide, nitrogen oxide, nitrogen dioxide, total particulates, and elemental composition by particle size. Measurements in the ambient included all of the preceding plus nitrates and nitric acid and all pertinent meteorological parameters required for dispersion model predictions of downwind concentrations. All sampling was carried out during a three week period in August, 1981.

SECTION 5

MEASUREMENT METHODS

SOURCE PARTICULATE EMISSIONS

Four types of particulate sampling were carried out on the sources during the test program. These included the measurement of total particulate emissions; particle size distribution measurements in both the sub-micron and super-micron portions of the particle size spectrum; and the acquisition of samples for elemental analysis by particle size. All source samples were taken from the stack(s) associated with each source. Samples for the determination of elemental composition by particle size were taken from only one stack for each class of sources, while total emission measurements and particle size distributions were measured individually for each stack.

Total particulate loadings were measured using a modification of EPA Method 17.[28] The modification was one intended to minimize the inclusion of H_2SO_4 in the sample. The samples were collected on quartz filter media in a heated filter holder. The sample was passed through a short (20cm) tubular heater located between the sampling nozzle and the filter holder before reaching the filter. The temperatures of the tube and filter holder were controlled to hold the gas temperature at the filter exit to 285°C (550°F) in order to minimize retention of any condensed sulfuric acid with the particulate sample.

Modified Pilat (University of Washington) Mark V cascade impactors were used to determine particle size distributions over the aerodynamic particle diameter range from about 0.5 to 20 µm.[29-40] In most cases, stainless steel substrates coated with amorphous polypropylene were used as collection surfaces in the impactors. Ghia Teflon membrane filters were used as the final filters.

Because of the very high sulfuric acid mist concentrations found in the emissions from the calciners at Cyanamid, quartz fiber substrates with a Kapton® film underliner were used there. The quartz fiber material served as a "blotter" to retain the liquid acid while the Kapton® isolated the acid laden substrates from the stainless steel holders. Blank runs were made periodically to insure that no uncorrectable biases occurred as a result of gas phase constituents of the sample stream reacting with the collection media.[41] In addition, at Union Camp, time integrated samples were taken on each unit using SoRI's Five Series Cyclone Samplers[42] to provide representative bulk samples in six size fractions from <0.3 μm to >8 μm for subsequent elemental analysis by x-ray fluorescence and neutron activation techniques. Other samples for elemental analysis were obtained using a specially constructed impactor (WDXRF impactor), designed by SoRI on another EPA contract,[43] which provides samples in a form that is immediately compatible with elemental analysis by x-ray fluorescence. This impactor provides seven size-separated fractions (six fractionation sizes) over the range from <0.5 μm to >16 μm. The sampling ports at Cyanamid would not permit the use of the cyclone or WDXRF impactor systems, so at that site samples were taken for neutron activation and sulfate analyses only using Pilat impactors with pure quartz substrates.

Diffusional sizing techniques were used to extend the size distribution information into the sub-micron range. An in-situ, screen type diffusion battery system developed by Lundgren[44] was used for this sampling. With this system, filter samples were obtained downstream of a series of diffusion batteries to provide data on the elemental composition by particle size of the submicron portion of the aerosol size spectrum. The final two cyclones of the SoRI series cyclone system were used as precollectors on the diffusion battery system to limit the maximum size of the particles entering the diffusion devices to diameters of about 1 μm. Where the flue gas temperatures permitted, Ghia Teflon membrane filters were used to collect the particles that penetrated the diffusion batteries for subsequent analysis. Pure quartz filters were used where the temperatures were too high for the Teflon media.

SOURCE H_2SO_4 AND GASEOUS SPECIES

Sulfuric acid determinations were made using the method described by Cheney and Homolya (C&H).[45] In this method, a flue gas sample is withdrawn through a heated quartz probe and is passed through a heated quartz filter to a temperature controlled condenser and final filter. The probe and heated filter are maintained at a high enough temperature to insure that any previously condensed sulfuric acid will be evaporated and passed to the condensation section where the bulk of the acid is removed by the condenser. Any acid which condenses and remains suspended as particles within the gas stream in the condenser is removed by the final filter and included with the condensate for analysis. After removal of the acid, the sample stream is passed through a series of peroxide bubblers to collect SO_2. The collected samples are analysed by titration with $Ba(ClO_4)_2$ using Thorin indicator.

NO_x emissions were measured using a ThermoElectron Model A10 continuous NO_x analyser which was calibrated twice daily using bottled zero and span gases. Only one NO_x analyser was available, so only spot measurements were made on each source.

Manual methods for O_2, CO_2, and H_2O (Orsat and Method 4)[28] provided the information needed for these constituents.

AMBIENT MEASUREMENT METHODS

Ambient data were taken using three mobile sampling stations provided by TRC. Two of these were set up in four wheel drive vehicles, and the third was based on a small van type vehicle.

Each mobile monitoring station was equipped with the following:

1. Air conditioning unit;
2. Integrated glass sampling manifold;
3. Instrument mounting intended to be capable of providing protection during transport;
4. Roof mounting for hi-volume samplers and meteorological equipment.

Electrical service was provided for each station by a portable diesel motor driven generator. The generators were located at least 100 feet away from the monitoring station in the downwind direction.

Air Quality Instrumentation

Air quality measurements were made using "state-of-the-art" equivalent or reference method instruments. The following instruments were used in the program:

SO_2 Monitor - Meloy SA185-2A;

NO_x, NO, NO_2 Monitor - Monitor Labs 8440E;

TSP/Particle Sizing - MISCO Model 680 high volume samplers equipped with Sierra 234 cascade impactors using glass fiber substrates and filters, and Lundgren cascade impactors using polymeric coated mylar substrates and teflon membrane filters;

Sulfate/Nitrate - Misco Model 680 high volume samplers using Teflon membrane filters followed by sodium chloride impregnated filters;

Sulfuric Acid - SoRI designed ambient sulfuric acid sampling system.[46]

The Meloy SA-185-2A uses the Flame Photometric Detection technique. Ambient air is drawn through an H_2S scrubber into the detector block and passes through a hydrogen rich flame. The intensity of light emitted by the sulfur species is measured by a photo-multiplier tube which produces a current output. The output is stabilized, linearized, and converted to a voltage proportional to the SO_2 concentration in the sample stream.

The ML 8440 analyzer uses a chemiluminescent technique for measurement of NO and a low temperature NO_2 to NO converter for NO_2 measurements. This analyzer, since it is a dual channel instrument, provides simultaneous detection of both NO and NO_x and thus eliminates the potential of skew error in the data.

The SO_2 and NO_x analyzers were calibrated daily using gas dilution systems. SO_2 and NO, contained in aluminum cylinders, were diluted to concentrations within the dynamic range of the instruments to measure data precision and validate accuracy. In addition, gas phase titration of NO was utilized to validate NO_2 data. Pollutant-free air was generated within the calibrator in an enclosed system that incorporates an ultra-violet light source and a charcoal scrubber.

Total suspended particulate samples were collected using the Misco 680 hi-volume samplers equipped with Sierra 234 cascade impactors. Each sampler was equipped with a flow controller to maintain a constant 40 cfm flow rate regardless of filter loading. They were also equipped with elapsed time meters to permit accurate determination of the total gas volumes sampled. Similar samplers without the Sierra impactors were used to obtain samples for sulfate, nitric acid, and nitrate analysis. Conventional glass fiber filter media were used in the impactor equipped samplers; these were analyzed gravimetrically to determine TSP concentrations.

Teflon membrane filters were used in sampling for sulfate, nitric acid and nitrates in order to minimize artifact formation. A sodium chloride impregnated filter was installed downstream of the teflon filter for the nitric acid determination.[47-52] After sampling, the filters were removed from the samplers and stored in protective containers for subsequent analysis. The sulfate analyses were made using ion chromotography on aqueous extractions from the filters.[48] The nitrate and nitric acid determinations were made using a Technicon Auto Analyzer in which the collected nitrates are diazotized and reacted with a Greiss agent to form an azo-dye which is determined spectrophotometrically. Segments of the teflon hi-vol filters were also submitted for x-ray fluorescence and neutron activation analyses to determine elemental compositions of the deposited particulate matter for use in apportioning the material found on the filters among the various possible sources. Unused filters from the same batch were retained for use as blanks.

Lundgren impactors[53] were used to collect samples for the determination of elemental concentrations by particle size. These samplers used slot type impaction nozzles and rotating drum collectors. The original design of the impactors used a slow rotation of the drum to provide a time resolved trace of the airborne particles.[53] However, for this application the drums were rotated at 1 rpm in order to obtain the uniform deposition over the collection surface that is needed for x-ray fluorescence analysis. A 0.5 mil mylar film coated with Hercules Afax 800 amorphous polypropylene was wrapped around the rotating drum as a collection substrate. The polypropylene is quite sticky at ambient temperatures and thus served to insure good retention of the impacted particles. Random selections of the prepared substrates and filters were retained as blanks for use in the subsequent analyses.

The sulfuric acid samplers[46] consisted of a diffusion dryer to reduce the moisture content of the sample stream, a cyclone to strip out particles larger than about 2 μm, a diffusion denuder for the removal of SO_2 and other acid vapors, and a second diffusion denuder for removal of basic vapors - especially ammonia. These components were followed by a temperature controlled, teflon lined, heating section in which any condensed sulfuric acid would be evaporated. Particulate matter was then removed by a teflon filter which passed the bulk of the acid vapor to a second teflon filter that was impregnated with KOH to bind the acid vapor that was passed to it. The filters were extracted separately and sulfate concentrations were determined for particulate and acid phase sulfate by ion chromatography.

Meteorological Instrumentation

Meteorological data were collected routinely during each test period. Data collected to identify dispersion characteristics were taken from a 10m meterological tower which was set up in turn at the plant around which the ambient sampling was concentrated. Additional meteorological data was obtained through periodic releases of temperature sonde balloons. Tracking of the balloon ascents provided data on upper air wind direction and speed in addition to the vertical temperature profile. The balloons were launched from the site of the 10m tower. A tethered balloon was initially set up to provide continuous 100 meter temperature differentials, however, it was destroyed by high winds when tropical storm Dennis passed through the area early in the test program.

Upper air measurements were made using pilot balloons and temperature sonde equipment. A standard mercury thermometer and a Bendix aspirated psychron system were used to obtain ambient temperature, dew point temperature, and relative humidity at the pilot balloon launch site. Upper level wind speed, wind direction, and balloon ascent rate were determined by tracking the pilot balloons with two theodolites. Balloon positions were recorded every minute to yield wind velocity and instrument height data. The temperature sonde recordings were then used to determine mixing depths.

SECTION 6

SOURCE EMISSION CHARACTERIZATIONS

MEASUREMENT PROTOCOL

Given the number of sources involved in the test program and the geographic separations of the sources, it was not possible to obtain continuous, or even periodic, samples of each source through the entire test program. Rather, sampling was done on a spot basis at each stack. A sampling team with the equipment needed for one of the test methods being employed would set up at each stack, in turn, and obtain sufficient data (sampling runs) to permit adequate characterization of that source before moving to the next. Separate teams were set up for H_2SO_4/SO_2, total particulate concentration, NO_x, particle size distribution, and elemental composition sampling. For the most part, at any given time the teams would be set up on different sources with all teams shifting sources at the same time. This scheme of "round-robin" measurements avoided problems that would have been posed by attempts to obtain simultaneous data at what were often cramped sampling platforms. In addition, comparable data are provided by many of the techniques - eg. measures of total particulate concentration by Method 17, cascade impactors, and the series cyclones. The round-robin sampling thus permitted some assessment of the constancy of the emissions from each source, which was important in that reasonable constancy had to be assumed in the emissions since continuous data would not be available for any of the target sources.

A summary of the emissions data for the two source complexes is given in Table 1. This table includes information on stack dimensions, flue gas conditions, volumetric flow rates and flue gas concentrations of particulates, H_2SO_4, SO_2, and NO_x.

ACID PLANT COMPLEX TEST RESULTS

The feedstock for the acid plant was a rather pure form of elemental sulfur which we believed would result in emissions that would be difficult to isolate from other sulfate sources in the absence of other tracers. The acid plant is a part of a titanium dioxide manufacturing facility, and the product acid is wholly utilized at the facility. Two TiO_2 production processes are used at the plant. One uses hydrochloric acid for ore digestion followed by oxidation in a pure oxygen environment, and was of no interest in this study because it is not a source of sulfates or

TABLE 1. SOURCE EMISSIONS SUMMARY

SOURCE AM.CYANAMID	GAS FLOW, actual cubic meters/sec	H2O %	TEMP. deg. C	STACK HGT., meters	STACK DIA., meters	PART. CONC., mg/dnm3	PART. SO4=, mg/dnm3	H2SO4 CONC., mg/dnm3 (C & H)	TOTAL SO4=, mg/am3	SO2, ppm	NOX, ppm
ACID PLANT	28.2	0	90.6	45.7	1.83	5.26	5.00	24.49	23.00	417	15
WEST CALCINER	34.9	21	68.3	56.4	2.13	206.00	200.00	223.07	136.00	787	32
EAST CALCINER	32.8	24	71.1	56.4	2.13	48.06	48.00	48.11	31.00	336	25
UNION CAMP											
12 REC. BOILER	115	29	151.7	71.3	1.83	22.88	13.50	.46	6.90	78	38
13 REC. BOILER	105	34	154.4	71.3	1.83	18.77	7.03	<.22	3.20	64	32
14 REC. BOILER	219	34	148.9	93.4	2.74	36.61	28.40	.88	13.30	2.5	42
12 SMELT TANK	10.9	36	73.9	70.3	1.52	252.00	22.00	<.22	12.00	16	1.8
13 SMELT TANK	11.5	36	73.9	70.3	1.52	252.00	29.00	<.22	16.00	14	.25
14 SMELT TANK	25.6	36	73.9	93.4	2.44	188.00	28.00	<.22	15.00	10	-
4 LIME KILN	24.1	41	76.7	41.6	1.98	352.00	60.80	-	30.00	26	45
5 LIME KILN	25.8	51	81.1	41.6	1.98	263.00	(40)	-	16.00	NA	46
6 LIME KILN	32.6	36	73.9	41.6	1.98	18.08	10.10	-	5.40	13	NA
11-12 PO. BLR.	360	16	218.3	93.9	5.49	222.00	6.00	<.22	3.20	4.7	95
10 POWER BLR.	108	12	190.6	56.9	3.35	-	-		-		140

nitrates and has very low particulate emission rates. The second process uses the sulfuric acid produced by the acid plant to digest the ore, which is then calcined to form the TiO_2 product. The spend acid and waste material from the ore digesters are conveyed to an on-site neutralization plant where the acid is reacted to form gypsum. The emissions from the calciner stacks were reputedly primarily TiO_2 which we felt could serve as a source tracer for the complex as a whole in the atmoshpere downwind of the plant. The acid plant itself operates with a completely clear stack, and it was believed that it would not have any distinctive "fingerprint" for use in quantifying its impact downwind. The calciners were located near the acid plant, and the dispersion characteristics of the calciner emissions were expected to be similar to those of the acid plant, thus the composition of the calciner emissions could be used as a marker for the entire complex. The sampling program for the acid plant source emissions was therefore set up to include the acid plant and the calciners. TiO_2 emissions are also associated with the product recovery and handling operations of the plant; no attempt was made to quantify the latter, which were expected to be small compared to those of the calciners. The general layout of the facility is shown in Figure 3.

Unit operations

The acid plant was operated at nominal capacity (700 tpd) on a 24-hour-per-day, seven-day-a-week schedule throughout the test program. Production figures for the calciners were not made available; however, they also operated throughout the tests on a round-the-clock, seven-day-a-week basis at relatively constant production rates. A mix of sulfur from two sources with purities of 95% and 99%, respectively, was used as feed material to the acid plant. The higher purity form comprised about 90% of the mix. The results of x-ray fluorescence and neutron activation analyses of samples of each of the sulfur feed materials are given in Appendix B. Samples of the feed material to the calciners were not made available.

Additional, low rate, sulfate emissions are produced from vents in the ore digesters. These emissions are normally well controlled by scrubbers, but on occasion pressure surges in the digesters cause pressure-release vents to open, resulting in short term (seconds to minutes) releases of high-concentration sulfuric acid aerosols. The concentrations of aerosolized acid in the near vicinity of the digesters is too great for human safety during some of these pressure surges. Consequently, no personnel (or testing, even compliance type) are permitted in the area of the digester stacks and vents while they are in operation.

The acid plant uses condensers for primary product collection followed by a Petersen scrubber for final collection and gas cleaning prior to discharge to the atmosphere. The calciner

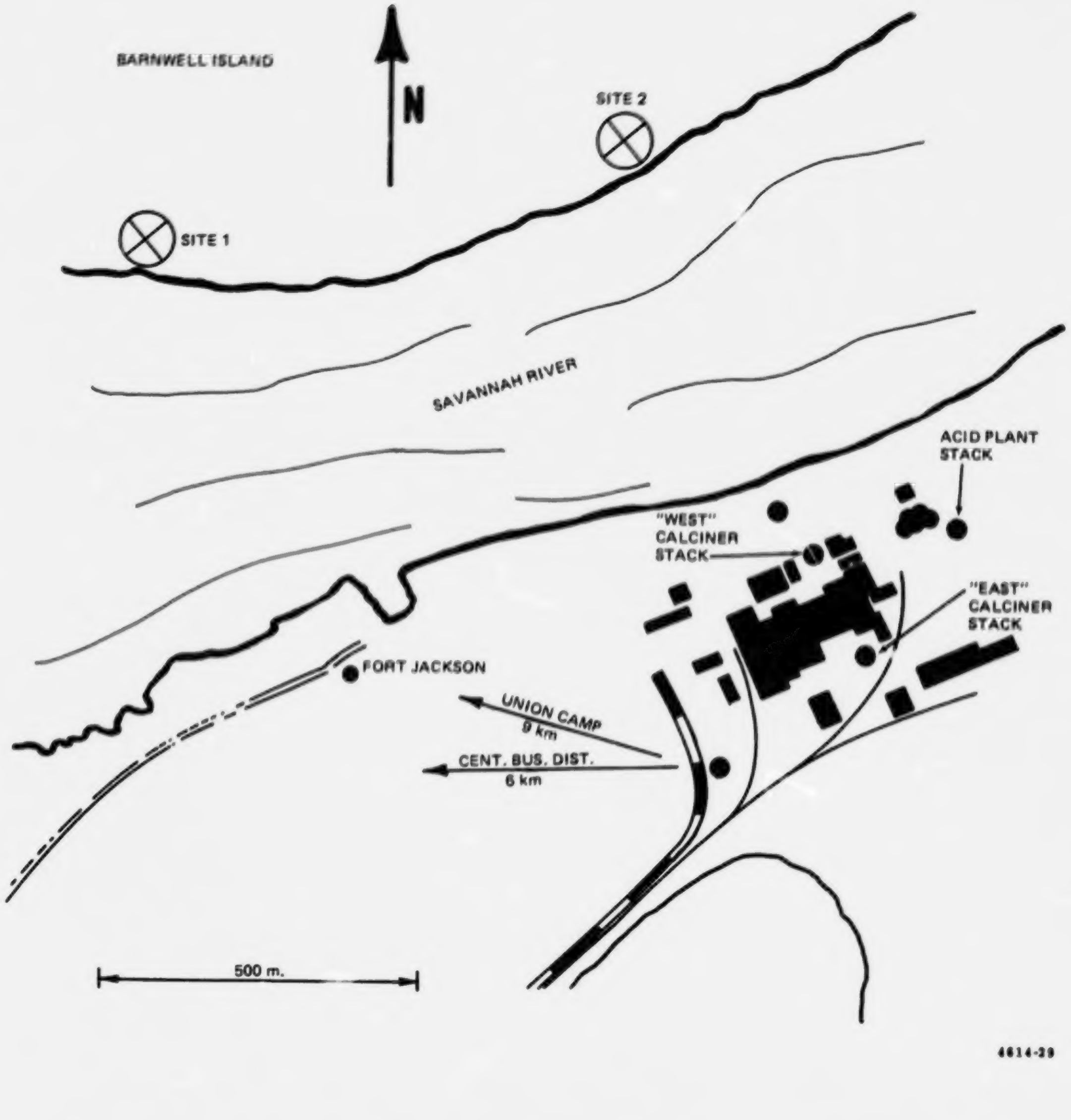

BARNWELL ISLAND
N
SITE 2
SITE 1
SAVANNAH RIVER
ACID PLANT STACK
"WEST" CALCINER STACK
"EAST" CALCINER STACK
FORT JACKSON
UNION CAMP 9 km
CENT. BUS. DIST. 6 km
500 m.
4614-29

Figure 3. Locations of principal sulfuric acid sources at the acid plant site.

exhaust gases are passed through water quench conditioning towers, a wet electrostatic precipitator, and a Petersen scrubber for emission control prior to discharge to the atmosphere. During the time in which this study was being carried out, the electrostatic precipitator on one of the two calciners was not in service because of a malfunction, resulting in somewhat higher than normal emissions from that unit.

Source test results

Total particulate concentrations measured using EPA Method 17 and cascade impactors are given in Table 2 together with SO_2 and H_2SO_4 concentrations.

The acid plant flue gases were dry (0% H_2O), and no problems were encountered in sampling at that location. The impactor runs were made at flue gas conditions while the Method 17 samples were collected after heating the gas stream to a temperature of 285°C to avoid retention of H_2SO_4. The similarity of the concentrations obtained using the modified Method 17 system and the impactors, taken together with the particulate sulfate concentration, leads to the conclusion that the bulk of the particulate matter in the acid plant flue gases is comprised of sulfate salts which make up only a small fraction (approx. 7 to 20%) of the total sulfate emissions from the plant when the vapor phase acid is included.

In the case of the calciner stacks, where entrained water was expected, the impactors were preceded by precollectors and extended inlet tubes. Both the extended inlet tubes and the impactors were heated. The temperatures of the inlet assemblies and the impactors were elevated so as to maintain an exit gas temperature about 12°C above the stack gas temperature. Previous experience in sampling at scrubber exits has shown that sampling in this manner will result in dry collection of particulate matter and the removal of a bias toward larger apparent particle sizes that would result if liquid water was present. Water droplets that are too large to evaporate in this fashion are removed by the precollector which precedes the heated assembly. Again, the Method 17 runs were to be made at much elevated sample stream temperature conditions to avoid inclusion of any sulfuric acid that might be present. In the event, it turned out that insufficient heat could be applied to either type of sampler to result in the collection of dry particles. The impactor stages collected a predominantly sub-micron liquid aerosol which would not dry in a dessicator or drying oven. A simple test with litmus paper indicated that the collected particles were strongly acidic (pH < = 1). By conditioning the filters and impaction substrates in an ammonia atmosphere the samples could be reacted to a dryable form. Sulfate analyses were performed on selected samples from both impactor and Method 17 runs with results that were included in Table 2. As can be seen by comparing the sulfuric acid concentrations obtained using the Cheney and Homolya condensation

TABLE 2. CYANAMID SOURCE EMISSIONS SUMMARY

SOURCE/ DATE	PARTICULATES, mg/dnm3		H_2SO_4 mg/dnm3	SULFATE, mg/dnm3		SO_2, PPM	
	IMPACTOR	METH.17	(C & H)	IMPACTOR	METH.17	(C & H)	METH17
ACID PLANT							
8/11		5.32	22.4			414	430
			18.4			408	
8/12	6.38						
8/13	1.87			1.3			
8/14							
WEST CALCINER							
8/11	144						
	234						
8/12		>70	191		141	770	
			191			802	
			184			790	
8/13		150					
		169					
8/14				175			
EAST CALCINER							
8/11							
8/12							
8/13		41	40		39	325	
			44			349	
			34			334	

method with the total particulate concentrations and the sulfates associated with the particulate samples, the supposed TiO_2 emissions from the calciners were in fact sulfuric acid.[2] The SO_2 concentrations measured in the calciner stacks were comparable to those in the acid plant stack in one case and about twice as high in the other. Referring again to Table 1, we find that ninety (90) percent of the sulfuric acid emissions and seventy-five (75) percent of the SO_2 emissions associated with the complex are produced by the calciners and not the acid plant.

Size fractionated samples for elemental analysis by neutron activation[57-59] were obtained on pure quartz substrates from both the acid plant and the calciners. The series cyclone system was not used in these applications because of a lack of suitable sampling ports - none of those available were large enough. The results of the NAA analyses on the acid plant samples and one of the two calciner samples is given in Table 3. It was concluded from these results that no elements were present in these sources at high enough concentrations for reliable detection and use as tracers for identifying contributions from the complex to the atmospheric burden downwind of the plant.

NO_x concentrations for the Cyanamid sources were 15 ppm for the acid plant, 32 ppm for the west calciner, and 25 ppm for the east calciner. These concentrations were determined using the previously described TECo Model A10 chemiluminescence analyser. NO_2 concentrations in all three sources were less than 1 ppm.

Particle size distributions for the acid plant and calciner emissions are given in Figure 4 on a cumulative concentration vs. particle diameter basis and in Figure 5 on a cumulative percentage of mass basis. The aerodynamic mass median diameter of the acid plant particulate emissions was about 4.5 μm and those of the calciners were about 0.4 μm.

PULP AND PAPER PLANT SOURCE TEST RESULTS

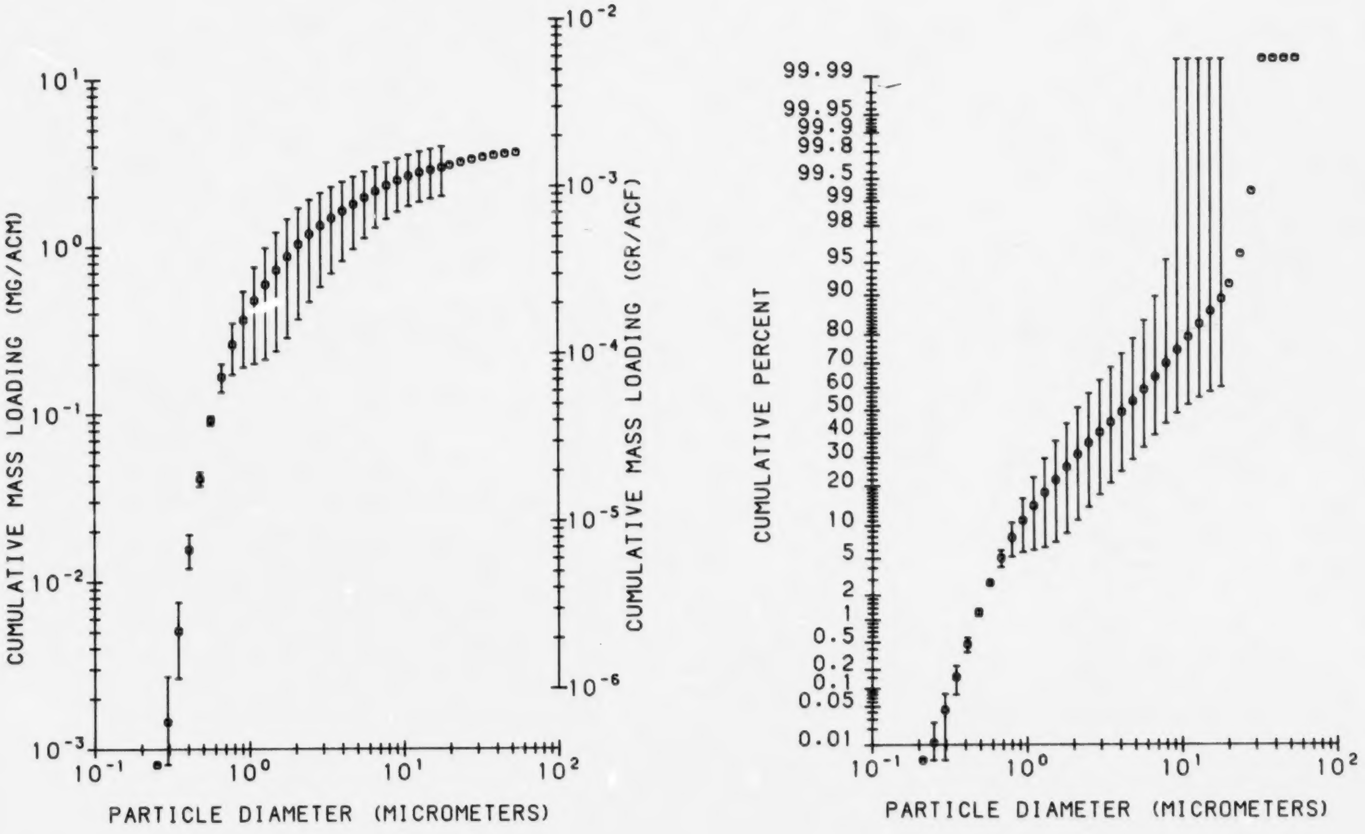
The major emission sources of interest at the pulp and paper complex were the recovery boilers, power boilers, and lime kilns. The recovery boilers and power boilers represent possible significant sources of oxides of sulfur and nitrogen, while the lime kilns were of interest primarily as particulate sources whose emission signatures would be convolved with those of the recovery and power boilers downwind of the plant. The general layout of the plant is illustrated in Figure 6.

Union Camp facility at Savannah is the world's largest pulp and paper mill with a Kraft pulp capacity of 2550 tons per day and a total pulp capacity of 2850 tons per day. The plant operates three recovery boilers, all designed by Combustion Engineering, three lime kilns, and three power boilers, two designed by Babcox and Wilcox and one by Combustion Engineering. Two of the three

TABLE 3. ELEMENTAL COMPOSITION BY SIZE FOR EMISSIONS OF THE ACID PLANT AND CALCINERS

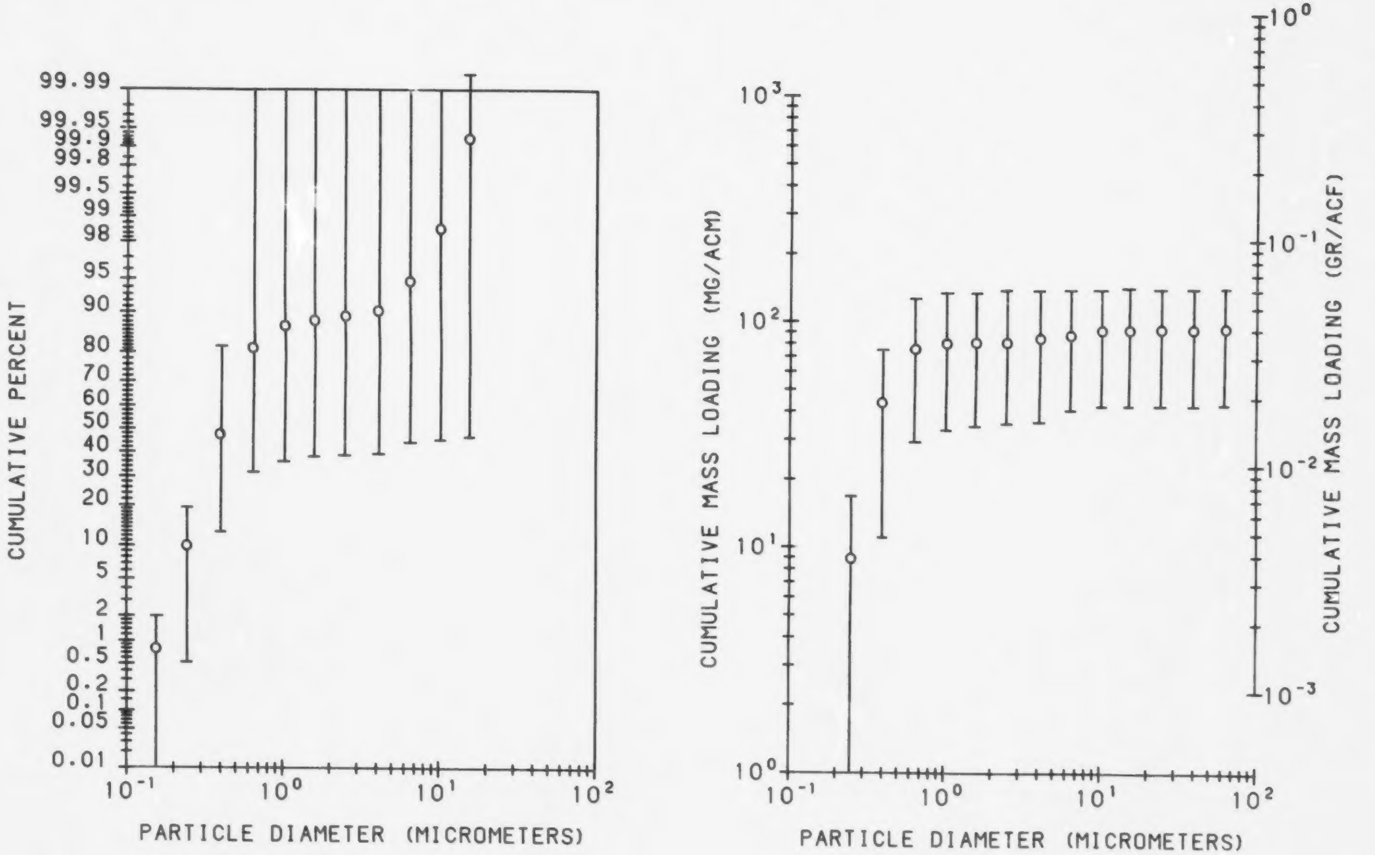
	Acid Plant				Calciners			
Diameter (um)	11.0-4.4	4.4-1.3	1.3-0.35	< 0.35	11.0-4.1	4.1-1.2	1.2-0.32	< 0.32
	1308COS2	1308COS3	1308COS5	1308COSF	1408COS2	1408COS3	1408COS5	1408COSF
AL	N.D.	N.D.	N.D.	2.16E+00	N.D.	N.D.	N.D.	2.53E+01
SI	N.D.	N.D.	N.D.	N.A.	N.D.	N.D.	N.D.	N.D.
P	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A
S	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
CL	N.D.	N.D.	N.D.	2.09E+00	N.D.	N.D.	N.D.	3.25E+00
K	N.A.	N.A.	N.A.	N.A.	N.A.	2.69E+01	N.A.	5.60E+00
CA	N.D.	N.D.	N.D.	N.D.	2.45E+01	N.D.	N.D.	N.D.
TI	N.D.	2.87E+00	N.D.	3.81E+00	3.59E+00	3.22E+00	8.60E+00	N.D.
V	2.00E-02	N.D.	2.00E-02	N.D.	1.00E-02	4.00E-02	N.D.	N.D.
CR	8.20E-02	9.00E-03	8.30E-02	7.89E-01	1.17E-01	2.17E-01	1.08E+01	7.90E-02
MN	6.00E-02	N.D.	N.D.	5.00E-02	N.D.	N.D.	3.50E-01	2.00E-02
FE	5.00E-01	3.15E+00	1.44E+00	1.25E+01	N.D.	N.D.	3.94E+01	2.88E+00
CO	9.00E-03	2.10E-02	2.60E-02	2.00E-02	9.00E-03	1.50E-02	7.70E-02	2.00E-03
NI	N.D.	4.12E+00	N.D.	N.A.	N.D.	5.64E+00	1.90E+01	2.80E-01
CU	N.D.	5.90E-01	N.D.	N.A.	N.D.	N.D.	N.D.	N.A.
ZN	9.77E-01	1.28E+00	1.37E+00	N.A.	8.27E-01	1.58E+00	1.86E+00	N.D.
GA	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
GE	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
AS	5.10E-02	N.D.	N.D.	2.60E-02	N.D.	6.21E-01	2.92E+00	7.97E-01
SE	4.16E-01	3.10E-01	1.56E-01	6.10E-02	6.40E-02	N.D.	7.72E-01	1.02E+00
BR	N.D.	N.D.	4.20E-02	1.90E-02	N.D.	N.D.	N.D.	N.D.
RB	N.A.	N.A.	N.A.	N.D.	N.A.	N.A.	1.21E-01	N.A.
SR	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
ZR	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PB	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
HG	1.73E-01	3.12E-01	3.05E-01	8.00E-03	1.19E-01	4.65E-01	1.53E+00	1.53E+00
W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CD	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	6.75E-01
SN	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
SB	1.70E+00	N.D.	4.47E-01	N.D.	1.66E+00	2.37E+00	1.25E+00	N.D.
BA	5.10E-01	7.21E+00	4.75E+00	N.A.	1.68E+00	5.78E+00	2.40E+00	6.05E+00
I	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
MG	N.D.	N.D.	N.D.	N.D.	N.D.	1.87E+00	N.D.	N.D.
NA	N.D.	N.D.	N.D.	1.57E+00	N.D.	N.D.	N.D.	N.D.
SM	N.D.	N.D.	1.10E-02	N.D.	9.00E-03	N.D.	N.D.	N.D.
CE	7.10E-02	8.50E-02	2.49E+01	N.D.	7.70E-02	4.21E-01	6.50E-02	N.D.
U	1.70E-02	N.D.	3.80E-02	N.D.	2.70E-02	N.D.	N.D.	2.20E-02
TH	1.40E-02	N.D.	9.00E-03	N.D.	N.D.	N.D.	N.D.	N.D.
LA	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
AU	2.00E-03	N.D.	N.D.	N.D.	3.00E-03	N.D.	2.00E-03	N.D.
AG	1.90E-02	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
SC	N.D.	4.00E-03	N.D.	1.00E-03	3.00E-03	5.00E-03	4.00E-03	N.D.
EU	4.00E-03	1.60E-02	1.10E-02	N.D.	4.00E-03	5.00E-03	1.10E-02	N.D.
CS	1.40E-01	1.81E-01	N.D.	N.D.	1.30E-01	1.82E-01	1.79E-01	N.D.
MO	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
LU	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
S4	5.96E+02	1.06E+03	8.05E+02	4.10E+01	7.74E+02	5.70E+03	1.06E+05	7.71E+03

* All units are micrograms/filter , Total S04 from filter extraction .



4614-30

Figure 4. Particle size distribution of the acid plant emissions on a cumulative concentration and cumulative percentage basis. Particle diameters are on an aerodynamic basis. Bars represent 90% confidence limits.



4614-31

Figure 5. Average particle size distribution of the calciner emissions. Particle diameters are on an aerodynamic basis. Bars represent 90% confidence limits.

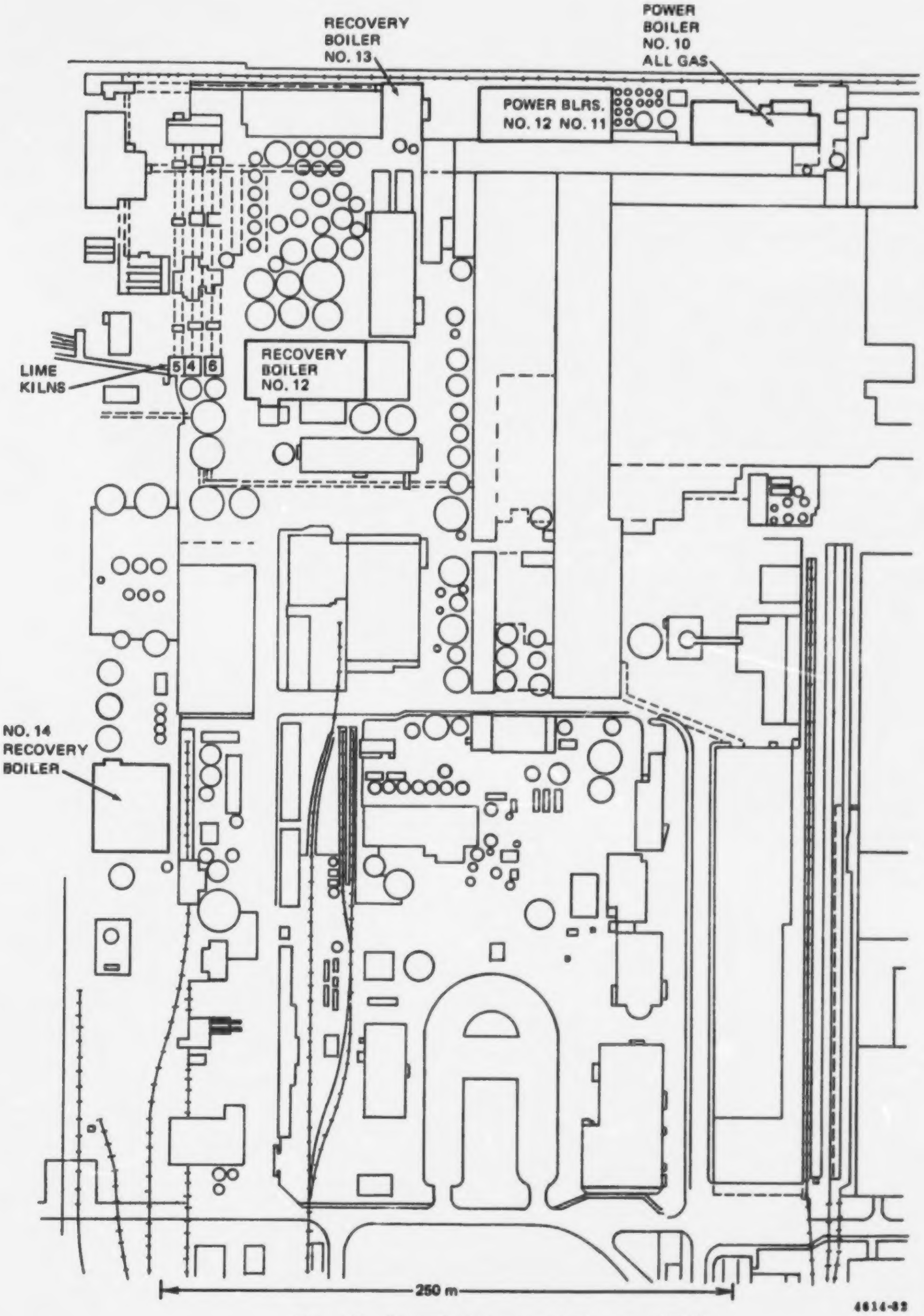

RECOVERY BOILER NO. 13
POWER BOILER NO. 10 ALL GAS
POWER BLRS. NO. 12 NO. 11
5 4 6
LIME KILNS
RECOVERY BOILER NO. 12
NO. 14 RECOVERY BOILER
250 m
4614-82

Figure 6. Layout of sources at the pulp mill site.

power boilers were fired primarily by bark and wood-waste with auxiliary gas or oil firing as required, while the third was fired with natural gas or oil only. At the time the test program was planned, it was expected that oil would be the supplementary fuel in use; however, the availability of cheaper natural gas at the time the tests were conducted resulted in no oil usage at all during the test period. Union Camp was in the process of constructing a new coal-supplemented hog-fuel power boiler at the time of these tests and intended to retire the existing power boilers upon completion of the new power plant.

Each recovery boiler had three stacks associated with it - two for discharge of combustion gases and one ventilating the smelt (recovered salt) dissolving tank. Electrostatic precipitators were used for particulate control for each of the boilers, and scrubbers were used for control of emissions from the smelt tank vents. The lime kilns utilized scrubbers for emissions control with a separate scrubber and stack for each kiln. The gas/oil fired boiler was not equipped with any control devices and discharged its combustion gases through a stub stack on the roof of the power house. The flue gases from the two bark-fired boilers were discharged through a common stack. A mechanical collector was used for particulate control on one of the two bark boilers, while the other used a Combustion Power Company gravel-bed filter. Stack dimensions, gas flows, and pollutant concentrations were summarized for all these sources in Table 1.

Unit operations

Production rates and control device operational details were not made available by the plant; however, daily average fuel firing rates were provided and are given in Appendix A. The three power boilers operated at relatively constant steam production rates throughout the period; however, the ratio of fuel usage between bark and natural gas was somewhat variable. One or another of the lime kilns was down throughout four of the test days and during parts of three additional days, with relatively constant production from each during the remainder of the time. With the exception of boiler No. 12, which was down for most of the final two days of the tests, the recovery boilers ran in a consistent manner throughout the tests.

The results of ultimate and proximate analyses of selected samples of black liquor solids and bark and wood-waste are given in Appendix B. All three recovery boilers are fired from a common black liquor source. The results of x-ray fluorescence and neutron activation analyses of lime kiln mud samples, black liquor samples, and bark samples are also given in Appendix B.

Source test results

Source measurements were made over the period 8/17 through 8/28. These included modified Method 17 sampling for total particulate emission rates, particle size distribution measurements using cascade impactors, obtaining size fractionated samples for elemental analysis using both the SoRI series cyclone system and a special "XRF compatible" impactor, SO_2 measurements by Method 6, NO_x measurement by means of a chemiluminescence-based continuous monitor and H_2SO_4 measurement using the controlled condensation technique developed by Cheney and Homolya.

Total particulate concentrations as measured by Method 17, cascade impactors, and cyclones are given in Tables 4, 5, and 6. The Method 17 and impactor samples were obtained by traverses of the stacks, while the cyclone samples were taken at single points in each stack. Only the Method 17 data were obtained under true isokinetic conditions, as the other two samplers must be operated at fixed flow rates. The impactors and cyclone samplers had external heat applied to them when sampling at scrubber exits to evaporate any entrained or condensed water. In this manner, the particles were sized, as nearly as possible, as they would exist after some residence time and drying in the atmosphere. The Method 17 samples were collected at elevated temperatures to avoid the inclusion of sulfuric acid, which was measured separately, as a part of the particulate emissions. In general, the concentrations determined by the various sampling methods agree favorably, except for notable discrepancies between Method 17 and the impactor and cyclone results for the lime kilns. Concentrations for the bark boilers and one each of the lime kilns, recovery boilers, and smelt tank vents were also determined from the WDXRF impactor runs and are included in the tables. These concentrations were obtained by summing the measured values for the individual elements that were detected and would be expected to be low by about a factor of about two because of undetected elements (principally carbon and oxygen).

Average particle size distributions for each class of sources are shown in Figures 7 through 10. These include data from both the impactor and cyclone runs. In each case, the distributions are multi-modal with one mode having a mass-median- diameter (MMD) near or under 1 μm and the second mode having a MMD between about 10 and 20 μm. Sixty to sixty-five percent of the emissions from the recovery boilers and smelt tank vents were in modes having MMD's of about 1 μm and eighty percent of the recovery boiler particulate mass emissions were in particles smaller than 10 μm. Sixty-six percent of the smelt tank vent emissions were smaller than 10 μm as measured; however, much of the remaining material was collected in the first stages of the samplers as liquid droplets and would have been smaller by an indeterminate amount if they had been dried before measurement. The data for the lime kilns, for which only about thirty-five percent of the mass, as

TABLE 4. RECOVERY AND POWER BOILER SULFATE AND PARTICULATE LOADINGS

	CONCENTRATION, mg/dnm3											
	NO. 12 RB			NO. 13 RB			NO. 14 RB			NO. 11/12 PB		
		PARTICULATE			PARTICULATE			PARTICULATE			PARTICULATE	
DATE	SO4=	METH17	IMPACT	SO4=	METH17	IMPACT	SO4=	METH17	IMPACT	SO4=	METH17	IMPACT
8/18									36.6*	19.00	672.8 67.1	
8/19												
8/20						26.5 19.7						
8/21												221.9 189.9 251.7
8/22												
8/23												
8/24	14.5 12.9	23.6 22.4							3.9**			
8/25										6		215.1
8/26									15.6			
8/27				7.03	13.5 14.6				47.8	6		43.5
8/28							28.4	60.4 23.6				

* Series cyclone (gravimetric)
** WDXRFimpactor (sum of elements as oxides)

TABLE 5. SMELT TANK VENT SULFATE AND PARTICULATE LOADINGS

	CONCENTRATION, mg/dnm3								
	NO. 12 STV			NO. 13 STV			NO. 14 STV		
		PARTICULATE			PARTICULATE			PARTICULATE	
DATE	SO4=	METH17	IMPACT	SO4=	METH17	IMPACT	SO4=	METH17	IMPACT
8/18						276.9 741.4			
8/19									
8/20									
8/21									
8/22									
8/23									400.5*
8/24									
8/25	21.7	228.8 274.6							36.6**
8/26				28.8	228.8 235.7				
8/27									210.5 121.3
8/28							27.8+	173.9 242.6	

* Series Cyclone (gravimetric)
** WDXRF Impactor (sum of elements as oxides)
+ 89% SO4= and 11% SO3- as SO4=

TABLE 6. LIME KILN PARTICULATE AND SULFATE LOADINGS

	CONCENTRATION, mg/dnm3								
	NO. 4			NO. 5			NO. 6		
		PARTICULATE							
DATE	SO4=	METH17	IMPACT	SO4=	METH17	IMPACT	SO4=	METH17	IMPACT
8/18									
8/19									
8/20	54.8 66.8	128 105							
8/21							10.1	17.6 20.1	
8/22									
8/23									
8/24									
8/25			643 538			446 151			
8/26									
8/27						277			
8/28						20			

* Series Cyclone (gravimetric)
** WDXRF Impactor (sum of elements as oxides)

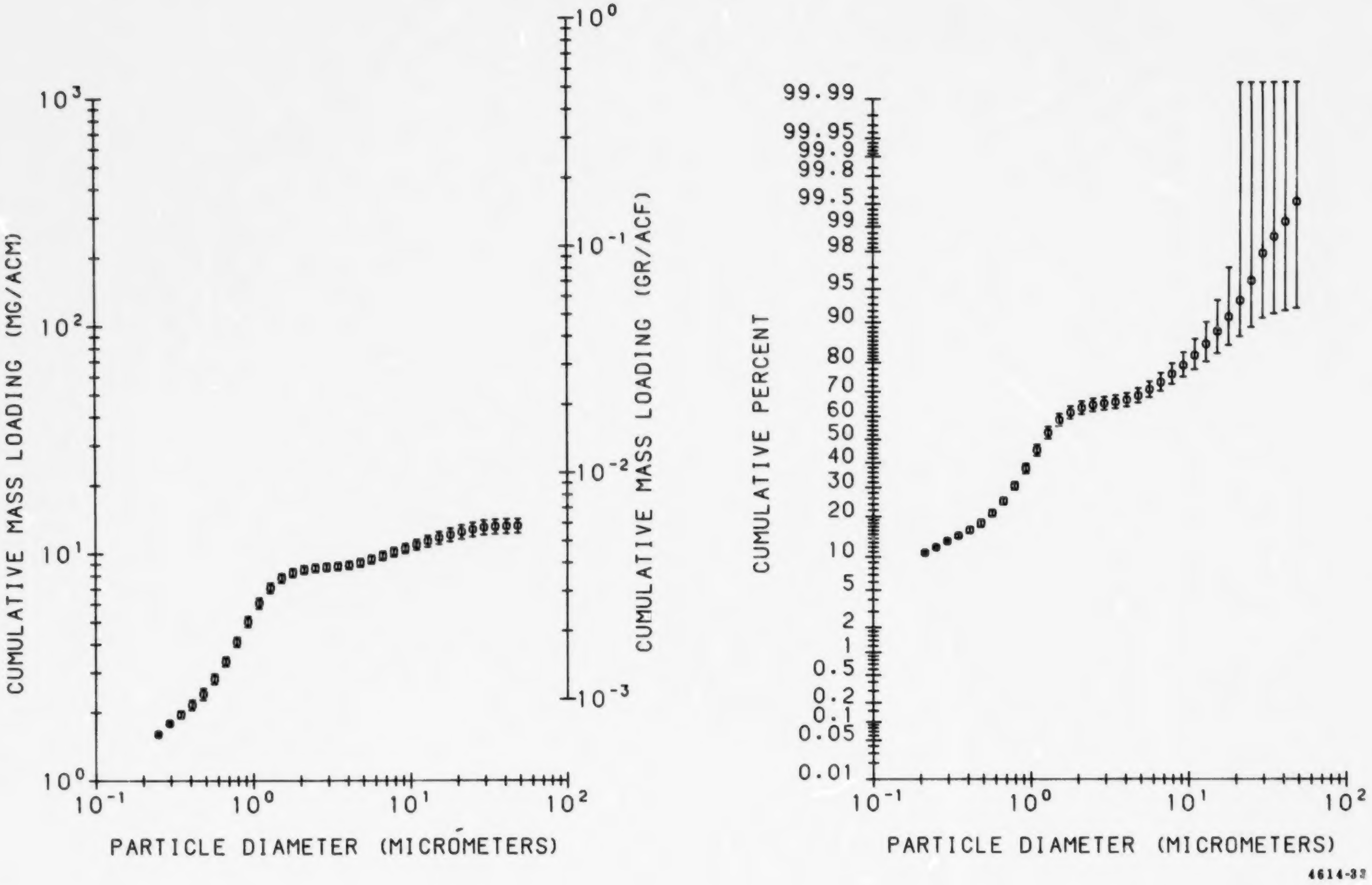


Figure 7. Average particle size distributions of the recovery boiler emissions. Particle diameters are on an aerodynamic basis. Bars represent 90% confidence limits.

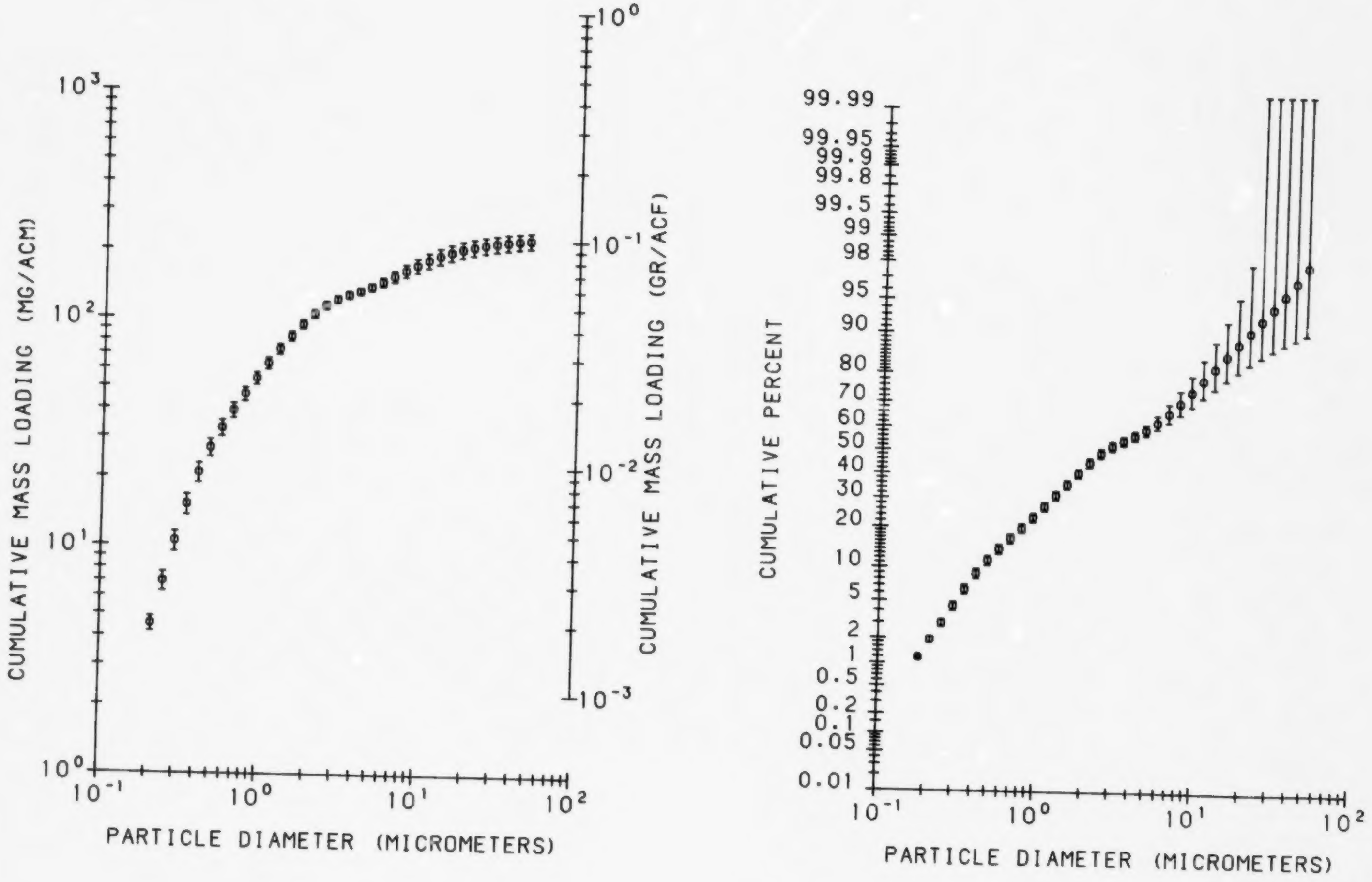
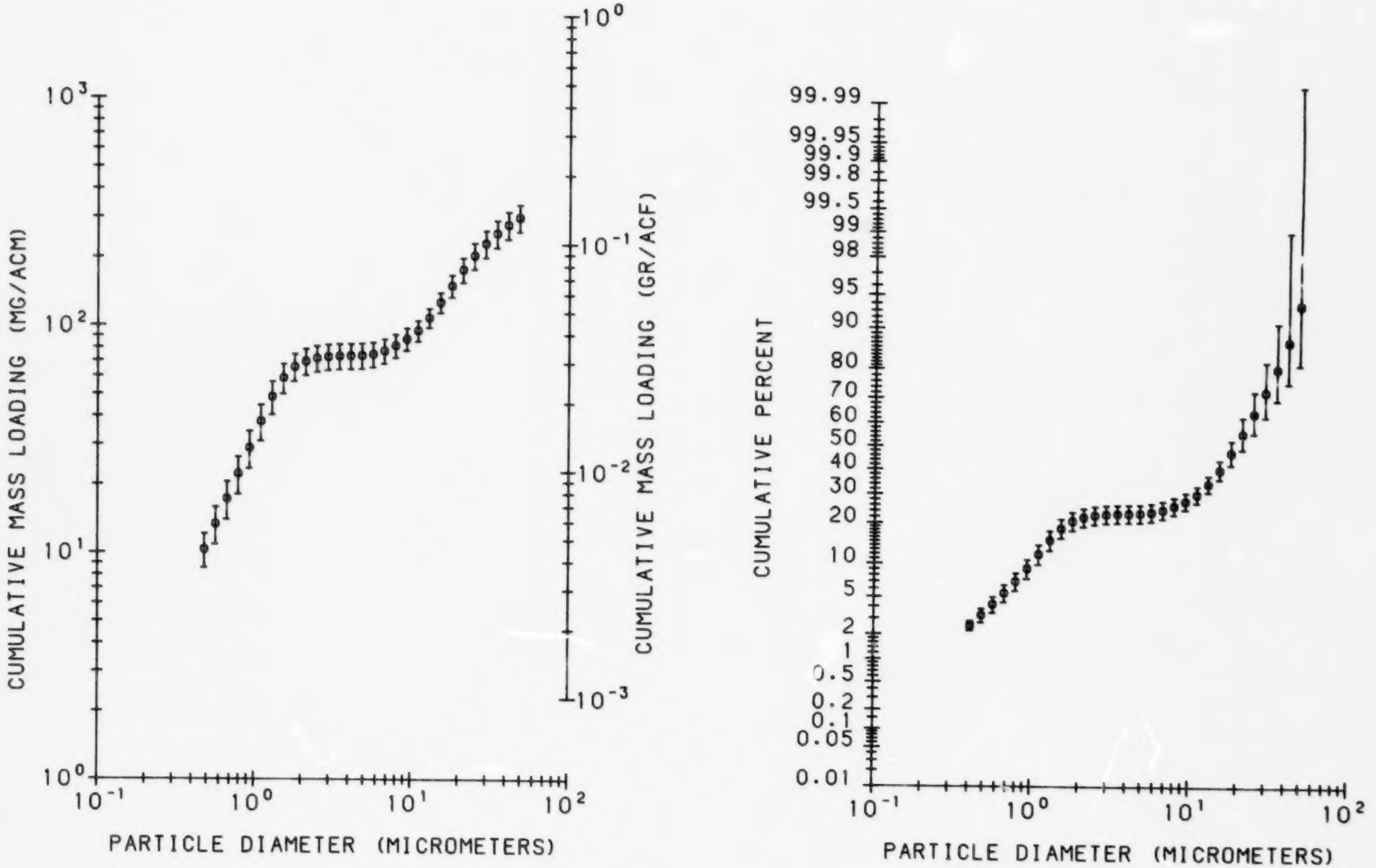
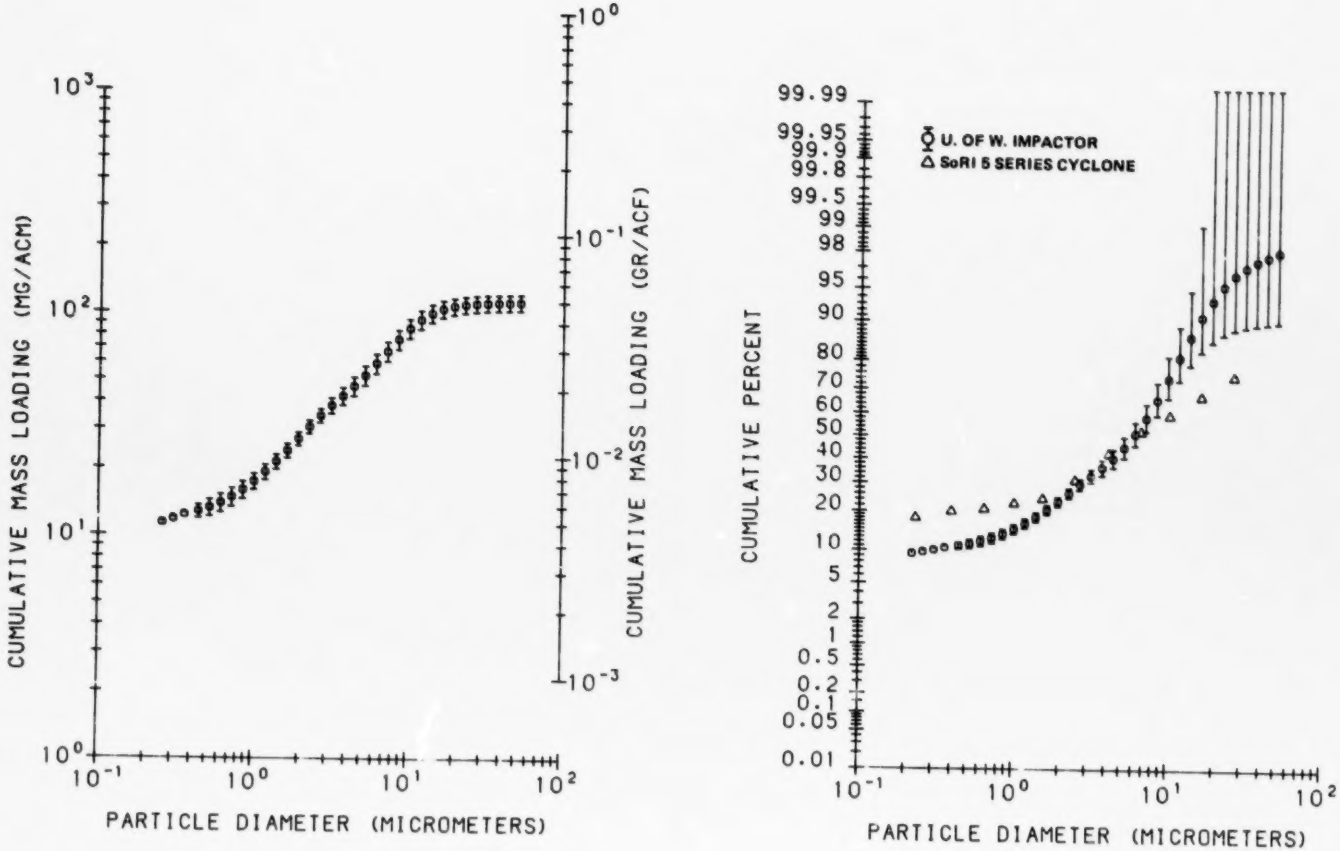


Figure 8. Average particle size distributions of the smelt tank vent emissions. Particle diameters are on an aerodynamic basis. Bars represent 90% confidence limits.



4614-35

Figure 9. Average particle size distributions at the Lime Kiln emissions. Particle diameters are on an aerodynamic basis. Bars represent 90% confidence limits.



4614-72

Figure 10. Particle size distribution of the bark-fired power boiler emissions on an aerodynamic diameter basis. Bars represent 90% confidence limits.

measured, was in the under 10 μm class is subject to a similar uncertainty. The bark-fired boiler emissions appeared to have a high carbon content and to consist of a submicron mode having an MMD near 0.1 μm containing ten percent of the emissions and a coarse mode with an MMD of about 10 μm which contained the remainder of the emissions.

Particle size distributions on an overall basis as determined from the WDXRF impactor are compared to those from the impactors and cyclone runs for the same sources in Figures 11, 12, and 13. As can be seen from the figures, the agreement between the results obtained by measuring individual element concentrations and those from independent gravimetric measurements is quite good. A malfunction in the drive system of the WDXRF impactor invalidated the results of the bark-fired boiler run for size distribution determination purposes, so no comparisons were possible for that source.

A screen type diffusion battery system was used to obtain estimates of the size distributions of the submicron components of the recovery boiler and bark-fired power boiler emissions. High entrained liquid concentrations in the smelt tank and lime kiln stacks caused operational problems with the device that could not be surmounted during these tests, so no data was obtained with the sampler for those sources. The diffusion batteries were preceded by the final two cyclones of the SoRI Five Series Cyclone System in order to eliminate particles larger than about 1 μm, which would bias the data (and perhaps plug the screens). Even with the cyclone precollectors, the first screen in each diffusion battery had a thick particulate cake build up on it before enough material for analysis could be collected on the after-filters at both of the two sources from which samples were obtained. Because of the screens plugging from this buildup, the data from the diffusion batteries were not deemed to be valid and therefore are not included in this report.

Concentrations of individual elements for each of the size fractions provided by the SoRI Five Series Cyclone System are given for each of the four classes of sources in Tables 7 through 10. The results of similar measurements using the WDXRF impactor are given in Tables 11 through 14. Only the overall concentrations reported for the bark-fired boiler from the WDXRF impactor data are valid because of the previously mentioned impactor drive malfunction. In the cases of the recovery boilers and smelt vent tanks, the measured elemental compositions in each of the fractions are reasonably consistent with the known bulk composition of recovery boiler effluents - largely sodium and potassium sulfate. The reported values are not in complete agreement with stoichometric ratios - probably as a result of inaccuracies in the corrections for absorption in the x-ray data.

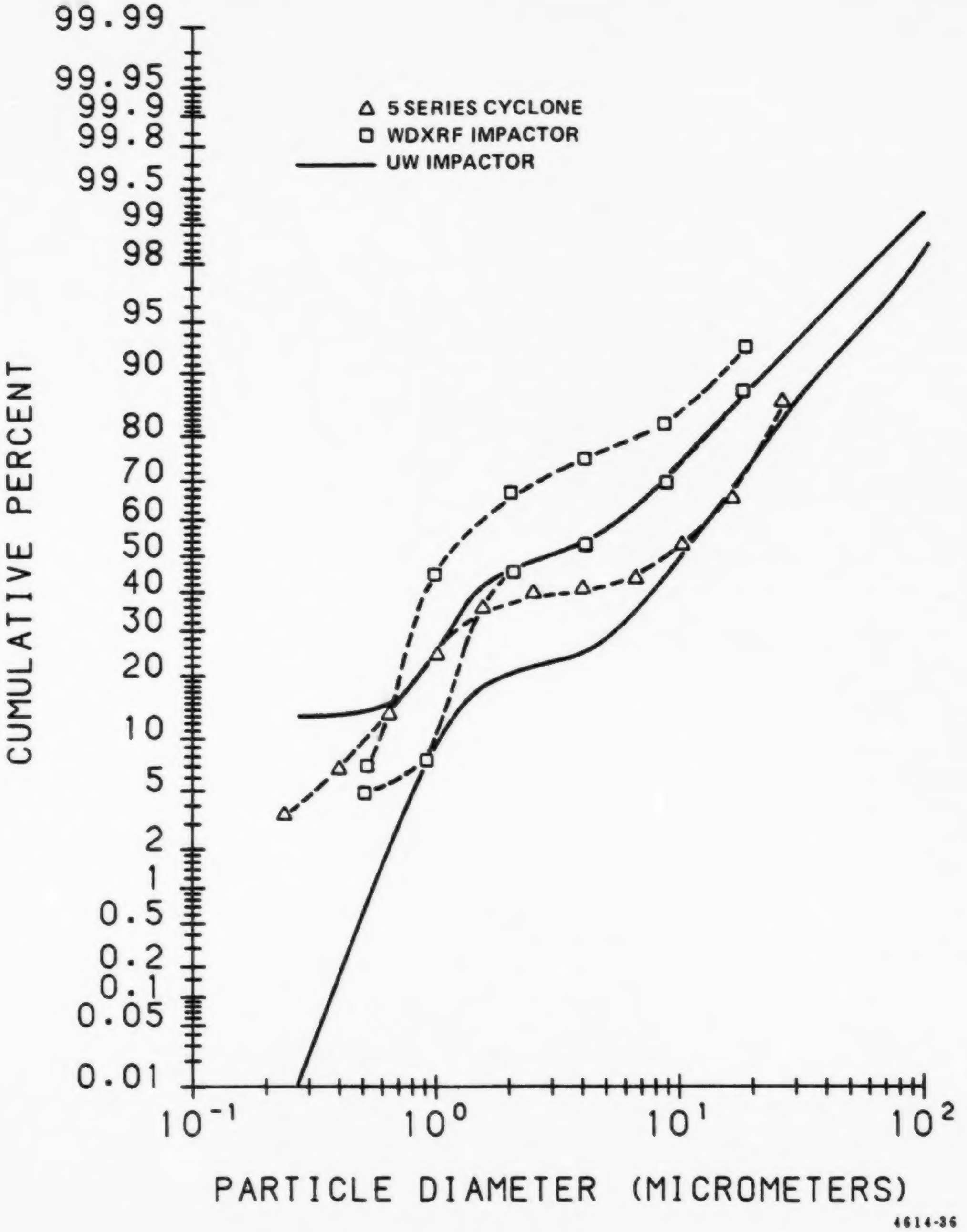


Figure 11. Comparison of size distributions of emissions from the No. 14 recovery boiler as measured by University of Washington cascade impactors, SoRI series cyclones, and the SoRI/EPA WDXRF compatible cascade impactor. Particle diameters are on an aerodynamic basis.

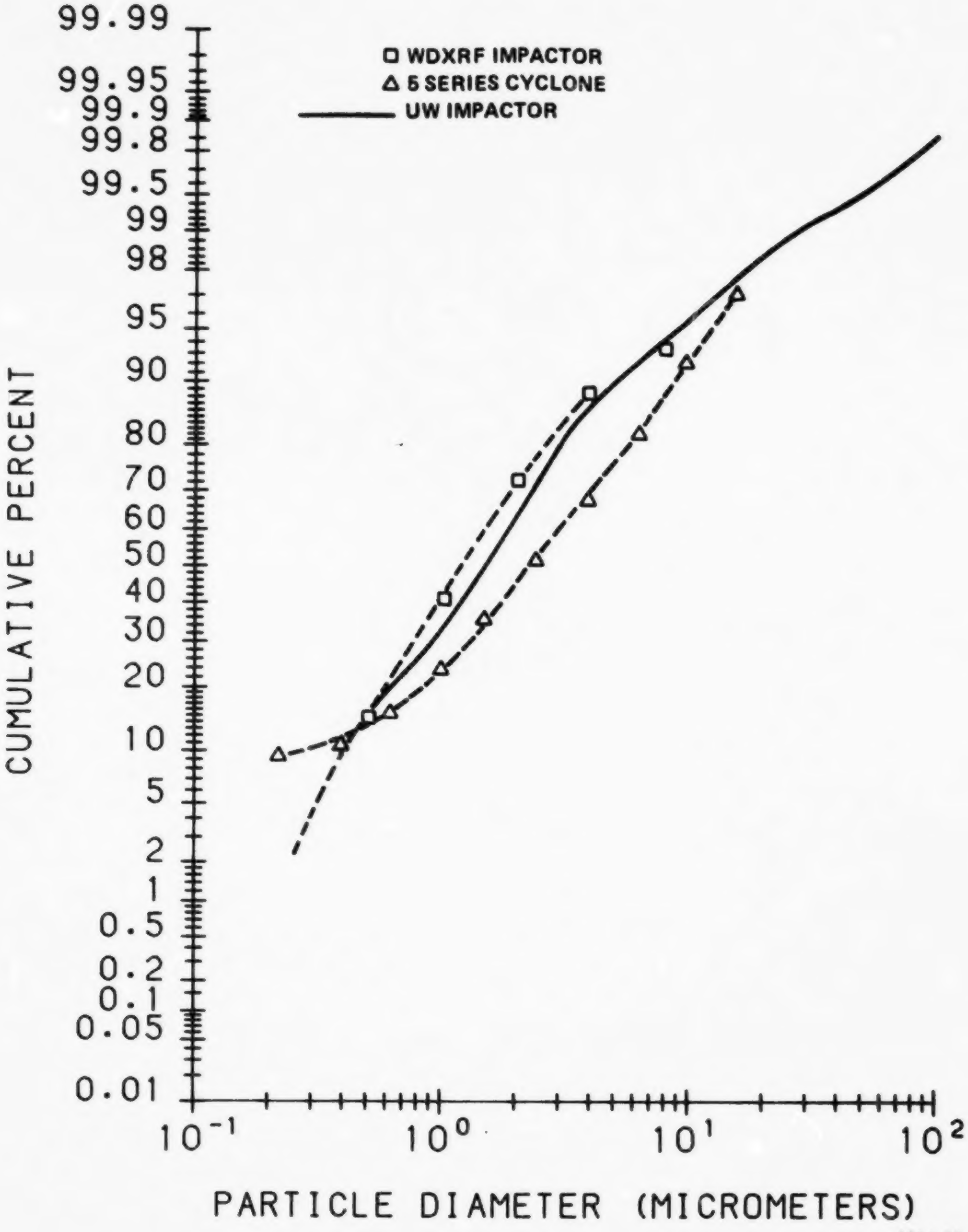
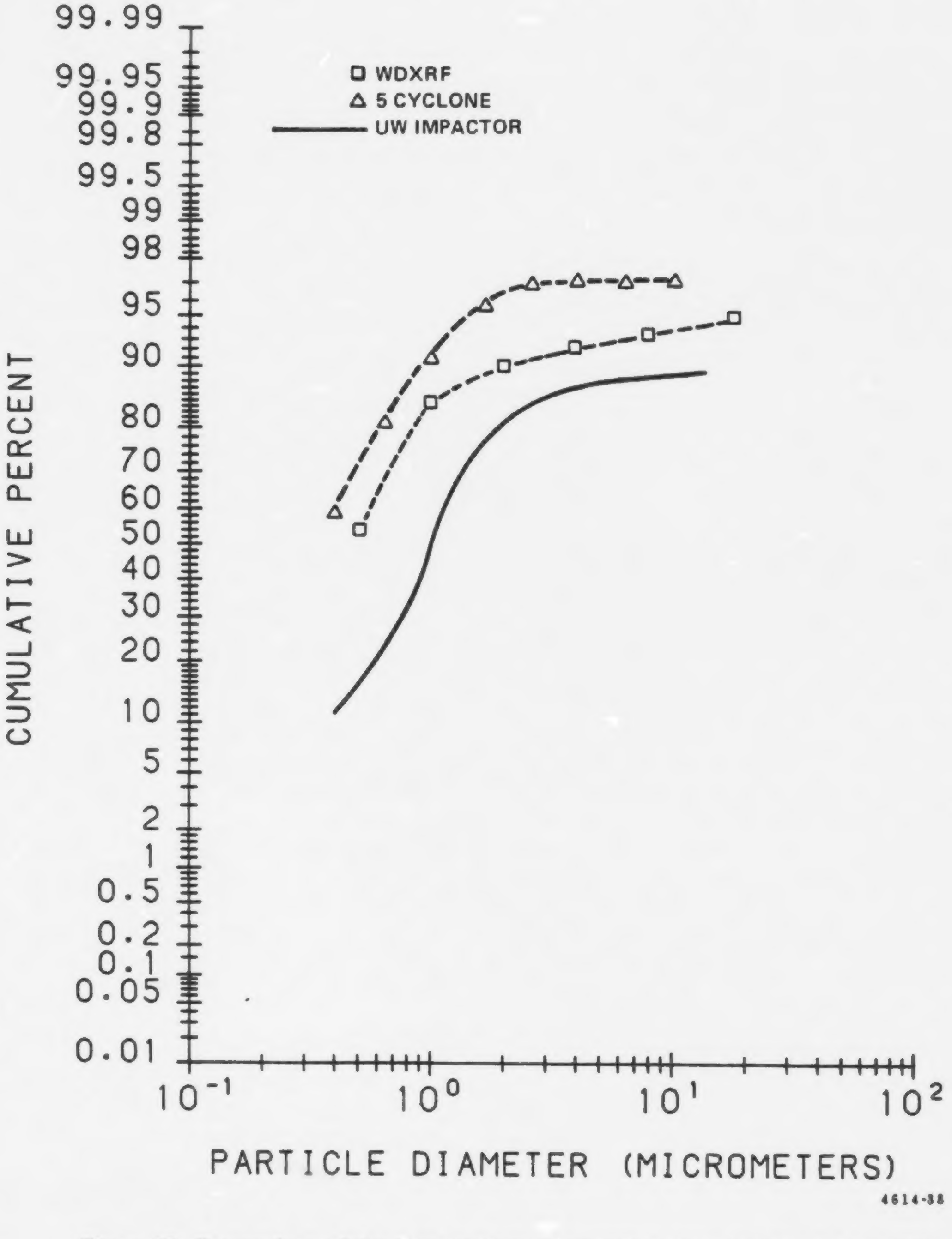


Figure 12. Comparison of size distributions of emissions from the No. 14 smelt tank vent as measured using University of Washington cascade impactors, SoRI series cyclones, and the SoRI/EPA WDXRF compatible impactor. Particle diameters are on an aerodynamic basis.



4614-38

Figure 13. Comparison of size distributions of emissions from the No. 5 Lime Kiln as measured using University of Washington cascade impactors, SoRI series cyclones, and the SoRI/EPA WDXRF compatible impactor. Particle diameters are on an aerodynamic basis.

TABLE 7. ELEMENTAL COMPOSITION BY SIZE FOR EMISSIONS OF THE RECOVERY BOILER

	Cyclone # 1		Cyclone # 2		Cyclone # 3		Cyclone # 4		Cyclone # 5		Filter	
	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY
AL	1.56E+03	8.10E+03	N.D.		N.D.		N.D.	4.00E+03	N.D.		2.35E+00	1.30E+00
SI	N.A.	9.60E+03	N.A.		N.A.		N.A.	7.40E+03	N.A.		N.A.	1.20E+00
P	N.A.	2.70E+03	N.A.		N.A.		N.A.	2.30E+03	N.A.		N.A.	N.D.
S	N.A.	1.91E+05	N.A.		N.A.		N.A.	1.36E+05	N.A.		N.A.	1.85E+01
CL	3.10E+04	1.99E+04	2.23E+04		2.43E+04		2.13E+04	1.37E+04	2.36E+04		8.08E+00	2.15E+00
K	N.A.	3.25E+04	3.19E+04		2.10E+04		4.65E+04	2.45E+04	2.16E+04		N.A.	3.10E+00
CA	N.A.	N.D.	N.A.		N.A.		N.A.	N.D.	N.A.		N.A.	N.D.
TI	N.A.	N.D.	N.A.		N.A.		N.A.	N.D.	N.A.		N.A.	N.D.
V	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		3.90E-02	2.20E-02
CR	1.37E+02	N.A.	2.66E+01		2.52E+01		3.11E+00	N.A.	3.46E+00		5.79E-01	N.A.
MN	2.50E+01	2.00E+02	2.14E+01		2.26E+01		1.83E+01	N.A.	1.50E+01		2.06E-01	N.A.
FE	7.14E+02	2.00E+02	3.15E+02		3.20E+02		1.15E+02	3.00E+02	2.70E+02		N.A.	1.38E-01
CO	8.90E-01	N.A.	1.90E-01		5.10E-01		1.60E-01	N.A.	6.80E-01		1.00E-02	N.A.
NI	N.A.	N.D.	N.A.		N.A.		N.A.	N.D.	N.A.		N.A.	N.D.
CU	N.A.	2.00E+02	N.A.		N.A.		N.A.	2.00E+02	N.A.		N.A.	N.D.
ZN	7.51E+01	2.00E+02	8.22E+01		8.27E+01		6.48E+01	3.00E+02	7.46E+01		4.62E-01	N.D.
GA	N.A.	N.D.	N.A.		N.A.		N.A.	N.D.	N.A.		N.A.	N.D.
GE	N.A.	N.D.	N.A.		N.A.		N.A.	N.D.	N.A.		N.A.	N.D.
AS	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
SE	N.D.	2.00E+02	N.D.		N.D.		N.D.	2.00E+02	1.79E+00		N.D.	N.A.
BR	1.95E+01	N.A.	1.15E+02		1.05E+02		1.19E+02	6.00E+02	8.77E+01		1.26E-01	6.00E-02
RB	3.21E+02	2.00E+02	2.45E+02		1.81E+02		3.46E+02	2.00E+02	2.69E+02		N.A.	N.D.
SR	N.A.	N.D.	N.A.		N.A.		N.A.	N.D.	N.A.		N.A.	N.D.
ZR	N.A.	N.D.	N.A.		N.A.		N.A.	N.D.	N.A.		N.A.	N.D.
PB	N.A.	N.D.	N.A.		N.A.		N.A.	N.D.	N.A.		N.A.	N.D.
HG	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		1.09E-01	N.A.
W	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
CD	N.D.	3.00E+02	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
SN	N.D.	2.00E+02	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
SB	N.D.	N.A.	7.10E-01		N.D.		N.D.	N.A.	N.D.		1.30E-02	N.A.
BA	N.A.	8.00E+02	N.A.		N.A.		N.A.	4.00E+02	N.A.		N.A.	2.78E-01
I	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		1.90E-02	N.A.
MG	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		3.17E+00	N.A.
NA	3.00E+04	N.A.	2.10E+05		2.52E+05		3.72E+05	N.A.	1.78E+05		1.61E+02	N.A.
SM	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
CE	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
U	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
TH	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
LA	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		5.00E-03	N.A.
AU	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
AG	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
SC	N.D.	N.A.	4.00E-02		1.50E-01		N.D.	N.A.	9.00E-02		N.D.	N.A.
EU	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
CS	N.D.	N.A.	1.08E+01		1.35E+01		N.D.	N.A.	9.93E+00		1.90E-02	N.A.
MO	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
LU	N.D.	N.A.	N.D.		N.D.		N.D.	N.A.	N.D.		N.D.	N.A.
Mass Conc. (mg/DNCM)	20.4		1.92		0.72		7.91		4.04		1.97	
Diameter (um)	>7.0		7.0 - 2.7		2.7 - 1.7		1.7 - 0.76		0.76 - 0.34		< 0.34	

* Units for Cyclone elemental concentrations are micrograms/gram ,
for filter , NAA results are micrograms/filter and XRAY results are micrograms/cm2 .

TABLE 8. ELEMENTAL COMPOSITION BY SIZE FOR EMISSIONS OF THE SMELT TANK VENT

	Cyclone # 1		Cyclone # 2		Cyclone # 3		Cyclone # 4		Cyclone # 5		Filter	
	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY
AL	N.D.	N.A.	N.D.	6.00E+02	N.D.	N.A.	N.D.	N.A.	3.62E+02			N.A.
SI	N.A.	1.60E+03	N.A.	3.30E+03	1.77E+04	4.20E+03	N.A.	4.70E+03	N.A.			3.00E+00
P	N.A.	4.00E+02	N.A.	7.00E+02	N.A.	9.00E+02	N.A.	1.20E+03	N.A.			1.12E-01
S	N.A.	1.87E+04	N.A.	3.34E+04	N.A.	4.07E+04	N.A.	5.05E+04	N.A.			2.65E+01
CL	3.53E+03	2.10E+03	7.83E+03	4.90E+03	8.39E+03	5.90E+03	1.06E+04	7.40E+03	1.70E+04			7.30E+00
K	4.90E+04	9.66E+03	N.A.	1.73E+04	N.A.	2.01E+04	N.A.	2.46E+04	3.79E+04			1.70E+01
CA	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.			N.D.
TI	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.			N.D.
V	N.D.	N.A.	7.76E+00	N.A.	1.43E+01	N.A.	1.24E+01	N.A.	2.07E+01			1.20E-02
CR	4.22E+00	N.A.	1.74E+00	N.A.	N.D.	N.A.	4.61E+00	N.A.	8.18E+00			N.A.
MN	3.55E+01	N.A.	6.12E+01	N.A.	5.23E+01	N.A.	4.94E+01	3.00E+02	5.29E+01			1.57E-01
FE	N.A.	2.00E+02	3.80E+01	N.D.	N.A.	2.00E+02	1.09E+02	2.00E+02	N.A.			N.D.
CO	3.50E-01	N.A.	7.20E-01	N.A.	4.20E-01	N.A.	2.20E-01	N.A.	3.62E+00			N.A.
NI	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	2.24E+02			N.D.
CU	N.A.	N.D.	N.A.	1.00E+02	N.A.	2.00E+02	N.A.	1.00E+02	N.A.			N.D.
ZN	N.A.	2.00E+02	8.83E+00	3.00E+02	N.A.	2.00E+02	1.35E+01	N.D.	1.35E+01			N.D.
GA	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.			N.D.
GE	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.			N.D.
AS	N.D.	N.A.	N.D.	N.A.	N.D.	2.00E+02	N.D.	N.A.	N.D.			N.A.
SE	N.D.	3.00E+02	N.D.	4.00E+02	N.D.	N.A.	N.D.	2.00E+02	N.D.			9.40E-02
BR	1.07E+01	2.00E+02	1.81E+01	N.A.	2.65E+01	3.00E+02	4.69E+01	2.00E+02	5.71E+01			1.90E-01
RB	1.57E+02	N.D.	1.70E+02	N.D.	2.47E+02	N.D.	3.20E+02	2.00E+02	2.96E+02			3.86E-01
SR	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.			N.D.
ZR	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.			N.D.
PB	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.			N.D.
HG	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
W	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
CD	2.09E+01	2.00E+02	N.D.	4.00E+02	N.D.	4.00E+02	N.D.	N.A.	N.D.			N.A.
SN	N.D.	N.A.	N.D.	6.00E+02	N.D.	6.00E+02	N.D.	N.A.	N.D.			N.A.
SB	N.D.	N.A.	N.D.	N.A.	6.30E-01	N.A.	9.30E-01	N.A.	2.43E+00			N.A.
BA	N.A.	N.D.	N.A.	1.50E+03	N.A.	1.40E+03	N.A.	N.D.	N.A.			N.D.
I	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
MG	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
NA	4.62E+05	N.A.	3.27E+05	N.A.	3.62E+05	N.A.	3.65E+05	N.A.	1.80E+05			N.A.
SM	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	1.40E-01	N.A.	N.D.			N.A.
CE	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
U	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
TH	N.D.	N.A.	5.00E-02	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
LA	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
AU	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
AG	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
SC	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	1.00E-02			N.A.
EU	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
CS	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	1.56E+01			N.A.
MO	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
LU	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.			N.A.
Mass Conc. (mg/DNCM)	116.1		147.6		63.0		56.0		18.4		36.8	
Diameter (um)	>4.8		4.8 - 1.8		1.8 - 1.1		1.1 - 0.47		0.47 - 0.19		< 0.19	

* Units for Cyclone elemental concentrations are micrograms/gram ,
for filter , NAA results are micrograms/filter and XRAY results are micrograms/cm2 .

TABLE 9. ELEMENTAL COMPOSITION BY SIZE FOR EMISSIONS OF THE POWER BOILER

	Cyclone # 1		Cyclone # 2		Cyclone # 3		Cyclone # 4		Cyclone # 5		Filter	
	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY
AL	2.98E+03		1.03E+03		6.90E+02		N.D.		N.D.	2.60E+03		N.A.
SI	N.A.		N.A.		N.A.		N.A.		N.A.	3.00E+03		1.40E+00
P	N.A.		N.A.		N.A.		N.A.		N.A.	1.00E+03		1.92E-01
S	N.A.		N.A.		N.A.		N.A.		N.A.	7.03E+04		1.34E+01
CL	7.42E+03		4.26E+03		8.38E+03		5.74E+03		1.10E+03	3.10E+03		5.70E+00
K	1.01E+04		3.11E+03		1.42E+04		N.A.		N.A.	9.43E+03		5.58E+00
CA	8.69E+04		N.A.		2.47E+03		N.A.		N.A.	6.60E+02		3.33E-01
TI	N.A.		N.A.		N.A.		N.A.		N.A.	N.D.		N.D.
V	4.42E+01		1.59E+02		N.D.		N.D.		1.44E+00	N.A.		1.70E-02
CR	2.29E+02		4.38E+01		1.96E+02		2.58E+02		2.87E+02	N.A.		N.A.
MN	1.75E+03		6.32E+01		1.92E+02		1.10E+02		9.10E+00	2.00E+02		1.50E-01
FE	1.08E+04		1.63E+03		1.16E+03		9.11E+02		7.13E+02	3.00E+02		2.31E-01
CO	3.60E+01		N.D.		1.17E+01		1.13E+01		8.84E+00	N.A.		N.A.
NI	1.66E+02		N.A.		N.A.		N.A.		3.08E+01	N.D.		N.D.
CU	1.50E+02		N.A.		N.A.		N.A.		N.A.	2.00E+02		7.60E-02
ZN	8.94E+02		9.95E+01		1.83E+03		1.59E+03		1.76E+03	7.00E+02		3.14E-01
GA	N.A.		N.A.		N.A.		N.A.		N.A.	N.D.		N.D.
GE	N.A.		N.A.		N.A.		N.A.		N.A.	N.D.		N.D.
AS	7.27E+00		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
SE	N.D.		1.58E+01		N.D.		N.D.		N.D.	2.00E+02		N.A.
BR	2.23E+00		3.19E+01		3.62E+01		5.19E+01		8.57E+01	N.A.		9.20E-02
RB	1.87E+01		7.46E+01		6.62E+01		1.88E+02		2.27E+02	N.D.		1.22E-01
SR	N.A.		N.A.		N.A.		N.A.		N.A.	N.D.		N.D.
ZR	N.A.		N.A.		N.A.		N.A.		N.A.	N.D.		N.D.
PB	N.A.		N.A.		N.A.		N.A.		N.A.	1.20E+03		4.57E-01
HG	1.48E+00		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
W	N.D.		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
CD	2.20E+02		N.D.		5.14E+01		2.17E+02		2.65E+02	N.A.		2.99E-01
SN	N.D.		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
SB	1.15E+00		5.69E+00		N.D.		N.D.		N.D.	N.A.		N.A.
BA	9.65E+01		3.22E+01		5.51E+01		2.20E+02		3.96E+02	N.D.		3.48E-01
I	N.D.		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
MG	4.55E+03		1.25E+03		N.D.		N.D.		N.D.	N.A.		N.A.
NA	7.84E+03		1.61E+05		1.52E+05		2.88E+05		3.40E+05	N.A.		N.A.
SM	5.10E-01		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
CE	7.70E+00		N.D.		1.93E+00		1.10E+00		N.D.	N.A.		N.A.
U	N.D.		N.D.		N.D.		N.D.		1.74E+00	N.A.		N.A.
TH	1.90E-01		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
LA	5.92E+00		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
AU	N.D.		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
AG	N.D.		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
SC	5.50E-01		3.20E-01		5.00E-02		N.D.		N.D.	N.A.		N.A.
EU	1.00E-01		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
CS	2.76E+00		1.45E+01		5.35E+00		N.D.		N.D.	N.A.		N.A.
MO	N.D.		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
LU	N.D.		N.D.		N.D.		N.D.		N.D.	N.A.		N.A.
Mass Conc. (mg/DNCM)	8.8		1.6		11.8		94.1		143.0		52.7	
Diameter (um)	>4.6		4.6 - 1.7		1.7 - 1.0		1.0 - 0.43		0.43 - 0.16		< 0.16	

# Units for Cyclone elemental concentrations are micrograms/gram ,
for filter , NAA results are micrograms/filter and XRAY results are micrograms/cm2 .

TABLE 10. ELEMENTAL COMPOSITION BY SIZE FOR EMISSIONS OF THE LIME KILN

	Cyclone # 1		Cyclone # 2		Cyclone # 3		Cyclone # 4		Cyclone # 5		Filter	
	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY	NAA	XRAY
AL	1.35E+04	2.27E+04	1.92E+04	2.42E+04	2.31E+04		2.46E+04		1.82E+04			N.A.
SI	N.A.	N.D.	2.05E+04	N.D.	N.A.		N.A.		N.A.			3.40E+00
P	N.A.	4.00E+03	N.A.	9.10E+03	N.A.		N.A.		N.A.			1.80E+00
S	N.A.	1.72E+04	N.A.	2.64E+04	N.A.		N.A.		N.A.			1.99E+01
CL	4.78E+03	4.20E+03	6.75E+03	6.00E+03	7.07E+03		1.02E+04		1.33E+04			4.98E+00
K	7.15E+04	3.09E+04	1.05E+05	4.49E+04	3.97E+04		4.62E+04		6.12E+04			3.10E+01
CA	3.94E+04	9.53E+04	3.23E+04	9.87E+04	4.45E+04		5.15E+04		3.71E+04			1.66E+00
TI	N.A.	2.30E+02	N.A.	5.30E+02	N.A.		N.A.		7.02E+02			N.D.
V	1.98E+01	N.A.	1.16E+01	N.A.	2.26E+01		2.54E+01		2.52E+01			4.80E-02
CR	3.25E+01	N.A.	3.80E+01	7.00E+02	3.89E+01		5.42E+01		5.69E+01			N.A.
MN	2.22E+03	2.60E+03	3.01E+03	3.60E+03	3.86E+03		4.31E+03		3.19E+03			2.64E-01
FE	7.87E+03	4.40E+03	7.82E+03	6.40E+03	7.96E+03		8.70E+03		7.25E+03			6.62E-01
CO	7.90E+00	N.A.	1.11E+01	N.A.	1.18E+01		1.45E+01		1.09E+01			N.A.
NI	4.79E+01	N.D.	N.A.	2.00E+02	N.A.		N.A.		8.79E+01			N.D.
CU	N.A.	4.00E+02	N.A.	3.00E+02	N.A.		6.00E+02		1.48E+02			7.30E-02
ZN	5.18E+02	6.00E+02	8.96E+02	1.00E+03	1.20E+03		1.61E+03		1.84E+03			6.11E-01
GA	N.A.	N.D.	N.A.	N.D.	N.A.		N.A.		N.A.			N.D.
GE	N.A.	N.D.	N.A.	N.D.	N.A.		N.A.		N.A.			N.D.
AS	3.20E+00	N.A.	5.61E+00	N.A.	3.94E+00		2.46E+00		9.03E+00			N.A.
SE	N.D.	1.00E+02	N.D.	4.00E+02	N.D.		1.30E+01		1.51E+01			N.A.
BR	3.23E+01	3.00E+02	4.69E+01	N.A.	3.83E+01		5.05E+01		8.27E+01			6.80E-02
RB	2.04E+02	4.00E+02	2.77E+02	N.D.	2.37E+00		3.43E+02		4.64E+02			1.48E-01
SR	N.A.	4.40E+02	N.A.	N.D.	N.A.		N.A.		N.A.			7.50E-02
ZR	N.A.	N.D.	N.A.	N.D.	N.A.		N.A.		N.A.			N.D.
PB	N.A.	6.00E+02	N.A.	1.10E+03	N.A.		N.A.		N.A.			2.49E-01
HG	9.81E-01	N.A.	1.23E+00	N.A.	N.D.		1.21E+00		1.24E+00			N.A.
W	N.D.	N.A.	N.D.	N.A.	N.D.		N.D.		N.D.			N.A.
CD	1.96E+00	N.A.	5.43E+00	N.A.	2.13E+01		2.44E+01		3.65E+01			N.A.
SN	N.D.	4.00E+02	N.D.	N.A.	N.D.		N.D.		N.D.			N.A.
SB	5.44E+00	3.00E+02	7.66E+00	N.A.	1.69E+01		2.42E+01		4.09E+01			N.A.
BA	1.49E+03	2.60E+03	2.16E+03	2.40E+03	6.14E+02		7.57E+02		5.88E+02			6.71E-01
I	1.32E+01	N.A.	N.D.	N.A.	N.D.		N.D.		N.D.			N.A.
MG	3.03E+03	N.A.	5.30E+03	N.A.	1.00E+04		1.18E+04		7.06E+03			N.A.
NA	7.60E+03	N.A.	1.00E+04	N.A.	6.03E+03		7.60E+03		1.11E+04			N.A.
SM	9.53E-01	N.A.	8.67E-01	N.A.	5.30E-01		6.10E-01		5.90E-01			N.A.
CE	1.14E+01	N.A.	1.19E+01	N.A.	1.32E+01		1.57E+01		6.96E+00			N.A.
U	1.25E-01	N.A.	N.D.	N.A.	N.D.		N.D.		N.D.			N.A.
TH	N.D.	N.A.	1.21E+00	N.A.	8.60E-01		1.03E+00		8.20E-01			N.A.
LA	8.56E+00	N.A.	9.26E+00	N.A.	5.36E+00		6.33E+00		7.32E+00			N.A.
AU	N.D.	N.A.	N.D.	N.A.	N.D.		N.D.		N.D.			N.A.
AG	N.D.	N.A.	N.D.	N.A.	N.D.		N.D.		N.D.			N.A.
SC	1.12E+00	N.A.	8.79E-01	N.A.	9.10E-01		9.00E-01		6.80E-01			N.A.
EU	2.27E-01	N.A.	2.07E-01	N.A.	7.00E-02		1.10E-01		1.00E-01			N.A.
CS	N.D.	N.A.	N.D.	N.A.	1.43E+01		1.64E+01		2.55E+01			N.A.
MO	N.D.	N.A.	N.D.	N.A.	N.D.		N.D.		N.D.			N.A.
LU	N.D.	N.A.	N.D.	N.A.	N.D.		N.D.		N.D.			N.A.
Mass Conc. (mg/DNCM)	112.8		48.1		30.2		18.7		5.8		53.3	
Diameter (um)	>9.3		9.3 - 3.6		3.6 - 2.3		2.3 - 1.0		1.0 - 0.45		< 0.45	

$ Units for Cyclone elemental concentrations are micrograms/gram ,
for filter , NAA results are micrograms/filter and XRAY results are micrograms/cm2 .

TABLE 11. WDXRF CASCADE IMPACTOR RESULTS FOR THE NO. 14 RECOVERY BOILER

	CONCENTRATION, UG/DNM3								CUMULATIVE PERCENTAGE THROUGH STAGE						
ELEMENT	PRE COL	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	FILTER	TOTAL	PRE COLL	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	FILTER
NA	39.77	68.29	35.00	85.08	168.17	381.30	49.08	826.69	100.00	95.19	86.93	82.69	72.40	52.06	5.94
MG	0.33	0.59	0.33	0.27	0.44	0.87	0.08	2.91	100.00	88.63	68.42	57.09	47.86	32.73	2.76
S	118.46	250.97	169.88	165.04	345.16	666.99	53.83	1770.32	100.00	93.31	79.13	69.54	60.21	40.72	3.04
CL	17.85	40.98	16.50	11.15	40.12	114.96	6.45	248.02	100.00	92.80	76.28	69.63	65.13	48.95	2.60
K	29.83	68.29	52.36	37.28	85.93	182.97	32.61	489.27	100.00	93.90	79.95	69.24	61.63	44.06	6.67
V	0.24	0.67	0.39	0.82	0.54	2.36	0.00	5.01	100.00	95.16	81.88	74.05	57.71	46.98	0.00
FE	3.49	1.71	0.75	0.21	0.22	0.00	4.20	10.57	100.00	67.03	50.86	43.78	41.78	39.68	39.68
CU	1.15	3.53	2.58	3.73	1.91	6.32	4.16	23.37	100.00	95.06	79.96	68.93	52.98	44.82	17.78
ZN	1.35	3.93	2.31	1.76	1.41	6.32	1.04	18.12	100.00	92.56	70.89	58.13	48.42	40.62	5.75
SE	0.83	2.50	1.62	3.27	0.28	3.41	5.50	17.41	100.00	95.25	80.90	71.62	52.83	51.20	31.59
BR	0.00	1.25	0.00	0.00	0.00	32.72	11.08	45.06	100.00	100.00	97.22	97.22	97.22	97.22	24.59
SR	4.96	14.57	14.60	16.90	9.59	79.96	18.88	159.46	100.00	96.89	87.75	78.60	68.00	61.98	11.84
MO	7.51	22.42	19.61	27.52	13.57	128.90	70.05	289.58	100.00	97.41	89.67	82.89	73.39	68.71	24.19
SN	0.38	3.76	7.34	8.45	5.18	0.50	0.96	26.57	100.00	98.58	84.44	56.81	25.00	5.51	3.62
W	0.55	3.22	2.30	2.68	1.41	10.70	11.79	32.65	100.00	98.32	88.47	81.41	73.20	68.89	36.12
PB	0.00	3.22	0.00	0.00	0.00	112.97	33.48	149.67	100.00	100.00	97.85	97.85	97.85	97.85	22.37
D50,UM										16	8	4	2	1	.5

TABLE 12. WDXRF IMPACTOR RESULTS FOR THE NO. 14 SMELT TANK VENT

	CONCENTRATION, UG/DNM3								CUMULATIVE PERCENTAGE THROUGH STAGE						
ELEMENT	PRE COLL	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	FILTER	TOTAL	PRE COLL	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	FILTER
NA	872.33	140.86	976.68	2612.70	4486.73	3688.11	2076.91	14854.32	100.00	94.13	93.18	86.60	69.02	38.61	13.98
MG	3.08	0.00	1.32	2.15	3.84	3.53	0.70	14.62	100.00	78.94	78.94	69.92	55.21	28.93	4.81
SI	25.17	13.28	30.32	45.84	36.32	28.56	36.05	215.53	100.00	88.32	82.16	68.09	46.83	29.98	16.72
S	435.17	107.89	454.84	1269.33	2861.28	2801.34	1248.11	9177.97	100.00	95.26	94.08	89.13	75.30	44.12	13.60
CL	60.61	236.24	157.61	442.50	627.61	664.63	458.54	2647.74	100.00	97.71	88.79	82.84	66.12	42.42	17.32
K	145.72	45.31	317.33	1546.11	2154.33	1680.10	821.45	6710.35	100.00	97.83	97.15	92.42	69.38	37.28	12.24
CR	0.84	11.35	4.27	1.03	2.01	15.95	1.35	36.80	100.00	97.71	66.86	55.27	52.48	47.02	3.67
MN	5.84	12.27	21.51	15.25	0.00	77.04	0.00	131.91	100.00	95.57	86.27	69.96	58.40	58.40	0.00
CU	0.00	0.00	0.00	4.90	0.00	31.20	27.46	63.57	100.00	100.00	100.00	100.00	92.29	92.29	43.20
ZN	3.76	8.99	1.07	10.17	0.00	40.20	15.52	79.72	100.00	95.28	84.00	82.65	69.89	69.89	19.47
SE	3.30	3.54	0.00	2.24	6.03	37.73	23.12	75.96	100.00	95.66	90.99	90.99	88.05	80.11	30.44
BR	0.54	0.00	1.83	0.00	2.75	197.45	13.93	216.50	100.00	99.75	99.75	98.91	98.91	97.64	6.43
SR	1.77	45.84	0.00	10.35	13.57	502.44	19.98	593.96	100.00	99.70	91.99	91.99	90.24	87.96	3.36
MO	4.19	84.80	0.00	14.00	35.44	837.40	289.35	1265.17	100.00	99.67	92.97	92.97	91.86	89.06	22.87
CD	0.63	1.66	1.18	2.17	3.00	0.34	0.15	9.13	100.00	93.06	74.87	61.94	38.20	5.38	1.69
PB	3.66	0.00	26.97	0.93	1.47	652.29	21.92	707.25	100.00	99.48	99.48	95.67	95.54	95.33	3.10
D50										16	8	4	2	1	.5

TABLE 13. WDXRF IMPACTOR RESULTS FOR THE NO. 5 LIME KILN

	CONCENTRATION, UG/DNM3								CUMULATIVE PERCENTAGE THROUGH STAGE						
ELEMENT	PRE COLL	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	FILTER	TOTAL	PRE COLL	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	FILTER
NA	16.09	19.26	7.75	38.23	247.31	948.40	3480.07	4757.10	100.00	99.66	99.26	99.09	98.29	93.09	73.16
MG	13.34	4.11	2.92	2.85	9.92	13.42	15.14	61.71	100.00	78.39	71.73	66.99	62.36	46.29	24.54
S	39.52	60.67	56.90	79.35	372.12	2325.39	5133.51	8067.46	100.00	99.51	98.76	98.05	97.07	92.46	63.63
CL	9.29	25.34	21.28	21.14	104.69	224.43	513.55	919.72	100.00	98.99	96.24	93.92	91.62	80.24	55.84
K	8.37	19.55	6.89	11.60	65.45	496.64	1004.95	1613.45	100.00	99.48	98.27	97.84	97.12	93.07	62.29
CA	848.16	5.55	0.00	0.00	38.08	86.73	93.65	1072.17	100.00	20.89	20.38	20.38	20.38	16.82	8.73
CR	7.77	0.00	0.00	5.62	5.62	16.07	11.66	46.74	100.00	83.37	83.37	83.37	71.35	59.33	24.95
MN	7.23	2.65	0.00	0.00	0.00	59.37	0.00	69.25	100.00	89.55	85.73	85.73	85.73	85.73	0.00
FE	52.64	22.15	3.82	18.68	20.13	12.68	15.27	145.37	100.00	63.79	48.55	45.92	33.07	19.23	10.50
CU	5.83	12.97	10.60	22.44	14.35	43.44	22.35	131.99	100.00	95.58	85.75	77.72	60.72	49.85	16.94
ZN	8.85	14.62	12.55	11.13	13.78	85.14	73.71	219.80	100.00	95.97	89.32	83.61	78.54	72.27	33.53
SE	3.80	9.22	14.09	17.81	10.93	11.21	12.39	79.44	100.00	95.22	83.61	65.88	43.46	29.70	15.59
BR	0.00	0.00	0.00	0.00	0.00	192.58	40.88	233.46	100.00	100.00	100.00	100.00	100.00	100.00	17.51
SR	30.61	77.75	80.51	86.59	62.99	438.73	70.49	847.66	100.00	96.39	87.22	77.72	67.50	60.07	8.32
MO	47.51	113.52	113.95	119.31	87.89	712.39	312.16	1506.73	100.00	96.85	89.31	81.75	73.83	68.00	20.72
CD	0.79	0.12	0.00	0.45	0.68	4.49	11.98	18.52	100.00	95.71	95.06	95.06	92.64	88.94	64.71
SN	23.76	28.09	31.28	40.25	29.39	43.00	7.13	202.90	100.00	88.29	74.45	59.03	39.19	24.71	3.51
BA	1.03	0.63	0.00	3.04	0.00	4.37	1.88	10.95	100.00	90.59	84.81	84.81	57.05	57.05	17.13
W	3.14	13.64	0.00	14.15	0.06	69.65	44.91	145.55	100.00	97.84	88.47	88.47	78.75	78.71	30.86
PB	0.00	0.00	0.00	0.00	0.00	677.64	157.69	835.33	100.00	100.00	100.00	100.00	100.00	100.00	18.88
D50										16	8	4	2	1	.5

TABLE 14. WDXRF IMPACTOR RESULTS FOR THE NO. 11/12 POWER BOILERS

ELEMENT	CONCENTRATION, UG/DNM3								CUMULATIVE PERCENTAGE THROUGH STAGE						
	PRE COLL	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	FILTER	TOTAL	PRE COLL	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	FILTER
NA	40.98	156.14	74.28	18.49	25.62	10.58	2087.46	2413.56	100.00	98.30	91.83	88.75	87.99	86.93	86.49
MG	129.44	218.30	130.98	46.54	14.60	5.37	1433.81	1979.04	100.00	93.46	82.43	75.81	73.46	72.72	72.45
AL	150.92	221.33	142.35	38.96	13.92	1.02	1355.79	1924.30	100.00	92.16	80.66	73.26	71.23	70.51	70.46
SI	224.97	285.00	162.21	30.93	12.52	0.00	953.06	1668.69	100.00	86.52	69.44	59.72	57.86	57.11	57.11
S	238.54	319.87	207.69	89.59	62.73	47.60	6011.46	6977.47	100.00	96.58	92.00	89.02	87.74	86.84	86.16
CL	47.09	181.92	103.39	39.26	37.90	17.74	2066.37	2493.66	100.00	98.11	90.82	86.67	85.10	83.58	82.86
K	322.19	591.23	392.63	172.82	140.98	105.36	11976.53	13701.75	100.00	97.65	93.33	90.47	89.21	88.18	87.41
CA	977.88	689.76	327.45	0.00	0.00	0.00	6431.06	8426.15	100.00	88.39	80.21	76.32	76.32	76.32	76.32
TI	10.46	18.95	13.80	6.06	6.64	2.71	31.21	89.83	100.00	88.36	67.26	51.90	45.15	37.76	34.74
V	2.58	5.88	3.88	2.76	5.32	4.06	0.00	24.48	100.00	89.47	65.45	49.60	38.33	16.59	0.00
CR	38.44	7.56	6.19	0.00	0.29	6.70	31.84	91.02	100.00	57.77	49.46	42.66	42.66	42.34	34.98
MN	19.95	127.34	121.58	114.30	95.20	87.02	295.20	860.59	100.00	97.68	82.88	68.76	55.48	44.41	34.30
FE	146.97	77.16	52.15	15.92	4.87	0.00	544.00	841.07	100.00	82.53	73.35	67.15	65.26	64.68	64.68
CU	2.52	27.74	20.62	18.04	16.68	14.43	53.14	153.16	100.00	98.35	80.24	66.78	55.00	44.11	34.69
SE	3.66	8.13	0.40	4.61	9.44	0.00	25.51	51.76	100.00	92.92	77.22	76.44	67.54	49.29	49.29
BR	0.00	23.50	1.02	11.16	7.40	2.30	84.97	130.35	100.00	100.00	81.97	81.19	72.63	66.96	65.19
SR	27.13	148.41	110.67	123.70	111.27	91.41	175.85	788.45	100.00	96.56	77.74	63.70	48.01	33.90	22.30
MO	31.77	222.85	154.63	171.30	177.37	137.95	459.66	1355.53	100.00	97.66	81.22	69.81	57.17	44.09	33.91
CD	1.09	3.00	1.53	0.00	0.08	0.31	14.76	20.77	100.00	94.77	80.32	72.95	72.95	72.55	71.07
SN	10.85	39.26	31.99	20.31	30.62	15.46	103.74	252.24	100.00	95.70	80.13	67.45	59.40	47.26	41.13
BA	10.97	15.16	9.23	4.71	3.52	1.58	146.33	191.50	100.00	94.27	86.36	81.54	79.07	77.24	76.41
W	0.88	12.67	16.83	10.01	14.30	4.94	81.18	140.80	100.00	99.38	90.38	78.43	71.32	61.17	57.66
PB	0.00	59.27	0.00	27.89	0.00	0.00	259.35	346.52	100.00	100.00	82.89	82.89	74.84	74.84	74.84
D50										16	8	4	2	1	.5

NOTE: DUE TO DRIVE MALFUNCTION, THE CONCENTRATIONS GIVEN FOR THE PRECOLLECTOR AND STAGES 1 THROUGH 5 ARE LOWER LIMITS AND THOSE FOR THE FILTER ARE UPPER LIMITS.

The samples for which XRF analyses are missing in Tables 7 through 10 contained small fractions of the combined material from all the cyclones. In each of these cases there was insufficient material to permit splitting the sample for parallel XRF and NAA analyses. When the sample cannot be split, it is preferable to do the NAA analysis first as was done here. It was intended that the samples with missing analyses be submitted for x-ray analysis following NAA but they were not returned by the analyzing laboratory in time for the second analysis to be performed. The lack of data for these cyclones is not critical, as only a small portion of the emissions were in the affected size ranges, and the remaining data do not suggest large composition variations by particle size. The composition data reported in these tables were used to generate a composite elemental emissions signature for the pulp plant complex for use in attempting to identify the plant's contribution to the ambient air particulate burden downwind.

Results of individual determinations of SO_2 and H_2SO_4 using the Cheney and Homolya (C & H) method are given in Table 15 for each of the various sources. This table also includes SO_2 and "H_2SO_4" measurements made in the course of the Method 17 sampling. The SO_2 data from the Method 17 runs are accurate; however, the H_2SO_4 values from these runs are only approximations. The latter were obtained by operating the Method 17 filter at an elevated temperature so that most of the sulfuric acid in the sample stream would be passed by the filter. The acid vapor was then passed to a filter which was mounted in an external oven in which the temperature was controlled at 60°C. The bulk of the sulfuric acid would be retained by the colder filter, from which it could be extracted and quantified. Because of time constraints, it would have been very difficult to obtain H_2SO_4 data on all thirteen of the stacks from which such emissions were possible using the C & H method. The cold filter technique in conjunction with the Method 17 tests were therefore used as a screening tool to insure that no source which had significant H_2SO_4 concentrations was omitted in the sampling with the controlled condensation technique. (Comparisons of similar Method 17 cold filter results with those obtained using the C & H method showed reasonably good agreement during the earlier, Phase 1, test program.)

The low SO_2 concentrations obtained for the No. 14 recovery boiler were considered suspect when the first two values were obtained. A second pair of measurements were made independently after making up fresh reagents and standards which confirmed the previous results - thus it appears that the concentrations for this unit, at this time were low. The combined SO_2 data from the Method 17 runs and the controlled condensation runs would support a hypothesis that the SO_2 emissions from the recovery boilers were variable on a day-to-day, or perhaps an hour-to-hour, basis. Unfortunately, with data available only on a spot basis, and only two days data for each unit, the hypothesis cannot be tested.

TABLE 15. UNION CAMP SO_2 CONCENTRATIONS

CONCENTRATION, PPM (V/V)

DATE	NO. 12 RB		NO. 13 RB		NO. 14 RB		NO. 11/12 PB	
	METH17	C&H	METH17	C&H	METH17	C&H	METH17	C&H
8/18		52					4.7	
		71					4.7	
		91					1.2	
		98						
8/21						2.3		
						1.1		
						5.6		
						.8		
8/24	8							
	26							
8/25				59				
				66				
				67				
8/27			61					
			56		40			
8/28					45			

DATE	NO. 12 STV		NO. 13 STV		NO. 14 STV		LIME KILNS	
	METH17	C&H	METH17	C&H	METH17	C&H	No. 4 METH17	No. 6 METH17
8/20		16					43	
		16					13	
		17						
8/21								15
								11
8/25	12							
	17							
8/26			12					
			16					
8/28					7			
					12			

Average NO_x concentrations for each of the sources were given in Table 1 and more detailed data are given in Table 16. Again, the long term stability of the concentrations for each of the sources could not be determined with the time and equipment available. Repeat measurements were made on 8/21 and 8/24 on No. 14 recovery boiler and on 8/25 and 8/26 on No. 11/12 power boiler which indicated that the NO_x emissions from these two sources were relatively stable. Ambient NO_x concentrations in the vicinities of the stacks were about 0.15 to 1.0 ppm - values which were comparable to those measured in the smelt tank vent exhaust streams. Thus it is probable that much of the NO_x found in the smelt tank gases was brought into the tanks with the incoming ventilation air.

TABLE 16. UNION CAMP NO_x CONCENTRATIONS

SOURCE	DATE	CONCENTRATION, PPM	
		RANGE	AVERAGE
12 RECOVERY BOILER	8/20	34-39	38
12 SMELT TANK VENT	8/20	1.5-2.5	1.8
14 RECOVERY BOILER	8/21	41-46	44
	8/24	35-43	39
13 RECOVERY BOILER	8/24	31-32	32
13 SMELT TANK VENT	8/25	0.15-0.35	0.2
11/12 POWER BOILERS	8/25	84-88	86
	8/26	72-112	95
10 POWER BOILER	8/26	130-145	140
4 LIME KILN	8/27	42-48	45
5 LIME KILN	8/27	44-48	46

SECTION 7

AMBIENT MEASUREMENTS

MONITORING SITE LOCATIONS

A grid of acceptable monitoring locations was developed in the vicinities of the plants and, based on anticipated wind flow, sites were selected for monitoring at the beginning of each test day. Wind flow was monitored throughout the course of each test day, and the sampling sites were changed when practical as the winds shifted in order to maximize the amount of data obtained in the plume. The movement of the sampling locations to remain in a plant plume obviously biases the samples toward over-estimation of the impact of the plant on the local surroundings. However, if fixed stations are used, one runs the risk of never sampling in the plume during a short term study of this type.

The monitoring sites were selected as much as possible in open areas where the prevailing wind flow was not significantly disturbed by local topography or vegetation. Also, sites near other local sites of pollutant emissions were avoided, although complete avoidance was not possible, especially downwind of the pulp mill. Selecting locations for the test sites was made more difficult because of the proximity of Savannah to the ocean. Seabreezes would set in during the early afternoon that would usually result in a 180 degree swing in the wind direction at the acid plant, with another reversal in direction in the late evening or early morning hours. The effect was less pronounced at the pulp mill site, which was located further inland. In fact, the surface winds at the acid plant and pulp mill were almost diametrically opposite in direction during the periods in which the on-shore winds were blowing. The distances involved in traveling from the north side of the river to the south side made it impractical to move sampling stations to accommodate the seabreeze wind shifts in the vicinity of the Cyanamid Plant.

A map of the study area was given in Figure 2 which showed the locations of the plants and the actual sampling sites that were used during the study. Table 17 identifies the bearing and distance of each monitoring location relative to the two source complexes. Sites 1 through 4, northwest of Cyanamid, were located on dykes surrounding U.S. Army Corps of Engineers dredge spoil dumping areas, in an area to which there was very limited access. The general public was not permitted in the area at all.

TABLE 17. LOCATIONS OF SAMPLING SITES RELATIVE TO PRINCIPAL SOURCES

SITE	CYANAMID		UNION CAMP		CENT. SAVAN.		PORT WENTWORTH	
	DIR. DEG.	DIST. KM	DIR. DEG.	DIST. KM	DIR. DEG.	DIST. KM	DIR. DEG.	DIST. KM
1	295	2.23	102	10.51	45	5.3	122	16.13
2	340	1.15	100	11.81	51	6.6	120	17.57
3	320	4.18	89	9.14	34	4.5	117	14.54
4	350	5.18	80	11.66	37	5.9	107	15.41
5	240	2.38	107	11.09	70	4.9	128	17.28
6	162	2.23	107	13.97	82	6.9	127	20.02
7	162	4.03	117	15.12	92	7.5	128	21.60
8	285	12.38	352	.86	340	5.1	147	7.06
9	277	14.69	240	3.10	317	5.8	176	8.35
10	274	15.05	234	3.89	311	6.0	179	9.07
11	262	12.82	183	4.75	311	3.4	166	11.95
12	272	17.28	230	6.34	298	6.9	189	10.80
13	262	15.12	206	5.69	298	5.3	177	11.81
14	250	12.82	176	7.63	283	3.8	165	14.83
15	255	24.48	227	14.98	243	12.6	204	18.72

TEST PROTOCOL

Data were collected using three mobile stations. One of these was utilized as an upwind monitoring station while the other two were positioned at differing distances downwind. Each station was equipped with:

1. analyzers to measure sulfur dioxide and nitrogen oxides;
2. one hi-vol TSP sampler equipped with a size fractionating head;
3. one hi-vol sampler using stacked teflon membrane and salt impregnated cellulose filters;
4. a Lundgren impactor;
5. a sulfuric acid mist sampler and;
6. bubblers for determining time-averaged SO_2 concentrations.

During each day of testing, meteorological data were collected to identify dispersion characteristics influencing emissions from the stacks. A typical daily measurement routine included the following:

1. Review the National Weather Service forecast for the day;
2. Launch the first upper air sounding balloon;
3. Establish the plume transport direction;
4. Deploy the mobile sampling stations;
5. Secure the mobile stations and conduct calibration of samplers and monitors;
6. Collect air quality data and monitor plume transport direction;
7. Shut down monitors and complete documentation of field activities;
8. Leave air quality monitoring sites and return to plant.

Upper air soundings were repeated periodically throughout the daily sampling period to document changes in upper level temperature profiles, wind speed, and wind direction.

TEST RESULTS

A summary of the ambient data is given in Table 18. All values given in this table insofar as possible represent averages over the time periods during which the hi-vol samplers for sulfate and nitrate determinations were in operation. Complete coincidence in timing was not always obtained with the Lundgren impactors and the sulfuric acid samplers.

A summary of the meteorological conditions for each day is given in Appendix C. Vertical atmospheric temperature profiles from the pilot balloon releases are shown in Figures 14 through 16. These show that the temperature lapse rate in the lower atmosphere was approximately adiabatic through most of the tests. On some occasions, inversions were found at altitudes that ranged from 250 to 1000 m. The mixing of air masses is inhibited at the elevation of such inversions. This causes pollutants emitted by the plant to remain close to the ground and slows the process by which they are diluted by the ambient air.

The data for each day are described more thoroughly in the following paragraphs. These detail the locations of the sites selected for each day's sampling efforts, and observed pollutant concentrations.

The measured concentrations of the gaseous pollutants over the entire test period were given in Table 18. Concentrations of NO_x and SO_2 (where available) are shown in graphic form together with wind direction information as appropriate in the paragraphs that follow. Concentration data on NO_x and SO_2 are fragmentary because of damage to the analysers that occurred in transit from Connecticut to Georgia. Much effort was expended in attempting to make the analysers serviceable, including flying in an instrument repair technician. In spite of all efforts, only one SO_2 analyser and two of the three NO_x analysers could be made operable. The one surviving SO_2 analyser was shortly rendered inoperable by ingestion of a massive dose of H_2SO_4 aerosol which destroyed its sensor. This event took place while sampling immediately downwind of the acid plant complex when the ore digesters suffered a pressure excursion which resulted in the release of a very dense cloud of sulfuric acid. At the time, the loss of the SO_2 analysers was not considered to be critical as peroxide bubblers were being used at each test site to obtain time integrated concentrations concurrent with the ambient sulfuric acid sampling.

Daily summaries

Test 1 - 8/11/81

During the morning and early afternoon the winds were from the west-northwest at 2 to 5 m/s with temperatures of about 33°C.

TABLE 10. SUMMARY OF AMBIENT SAMPLING RESULTS

			% WIND DIREC WITHIN +/- 30 DEGREES *		WIND DIR. PARAMETER **			SULFATE CONC., UG/M3							TSP						SO2				NITRATE	
							WIND SPEED	LUND.	ACID SYS.	HIVOL	HIVOL	LUND.	ACID SYS.		HIVOL			LUNDGREN			PPM		NO	NOX	HNO3	PART.
DATE	FILTER	SITE	CYAN	U.C.	CYAN	U.C.	M/S	TOTAL	TOTAL	(IC)	(XRF)	FILT.	PART	H2SO4	UG/M3	START	END	UG/M3	START	END	BUB.	MELOY	PPM	PPM	UG/M3	UG/M3
11	27	5	0	0	.14	0.00	4-5		NA	.86	3.05		NA	NA	63	1436	2050	NA			NA		21.60	74.00	.45	.56
11	26	1	100	0	9.00	0.00				4.03	8.95	.02			80	1507	1840	130	1702	2007			NA	NA	1.73	.69
		1	100	0					4.81			.02	1.41	3.40				130			428					
11	28	3	100	0	3.33	0.00			NA	.90	1.36		NA	NA	62	1645	1945	NA			NA		NA	NA	2.60	1.95
12	31	5	12	25	1.43	1.86	2-7		NA	2.33	4.96	4.56	NA	NA	35	1140	1920	251	1227	1600	NA		NA	NA	1.44	.60
12	30	3	25	30	2.50	.25		8.84	NA	2.43	4.74	3.06	NA	NA	0	1335	1755	305	1451	1743	352		NA	NA	2.50	.47
15		4	25				3-4					4.10						214	1639	2031						
15-16	1	2	29	62	2.70	4.71	2-4			8.25	15.30	NA			78	1900	1552	68	2004	1216			NA	NA	1.52	.30
15-16	2	4	29	47	2.01	2.95		9.96		8.47	11.70	3.14			NA	1724	1415	52	2024	1100		4500	NA	6.33	1.41	.44
16	3	5	0	67	0.00	5.50	2-6			6.15	8.40				36	935	1013						NA	NA	1.47	.10
16		5	0	0				27.2	6.67			4.04	2.50	4.17				239	1717	1957	275					
16		2	43	57				10.90	3.79			6.02	1.01	1.90				148	1320	2020	344					
16		4	40	50				16.40	2.16			6.02	.59	1.57				90	1116	2103	337					
16-17	34	2	33	25	2.00	1.50	2-6		NA	5.73	8.71		NA	NA	38	1616	1550				NA		NA	NA	1.45	.26
17	35	5	25	0	1.00	0.00	4-6	8.35	1.40	NA		2.00	.77	.63	NA	NA	NA	219	1531	1927	36		NA	NA	NA	NA
17	33	4	12	25	1.25	1.06	1-6		2.60	6.30	8.73	2.61	.67	1.73	85	930	1720	297	1030	1010	125		NA	NA	1.74	.50
17		2	12	25								3.12						131	1000	1751						
17-18	36	2	0	0	0.00	0.00	3-8		NA	6.62	7.59		NA	NA	28	1554	830	NA			NA		NA	NA	.57	.16
17-18	37	4	0	0	.12	0.00			NA	8.13	1.05		NA	NA	24	1745	1022	NA			NA		NA	NA	2.92	.00
18	38	2	0	0	0.00	0.00	8-9		NA	5.41	8.25		NA	NA	39	840	1525	NA			NA		NA	NA	.70	.70
18	41	4	0	0	0.00	0.00		7.66	3.44	4.48	7.33	2.02	1.54	1.90	37	1040	1530	172	1043	1714	74		NA	NA	.81	.27
20	46	5	0	0	0.00	0.00	3-5	7.58	1.10	5.50	7.49	2.20	.45	.73	59	1030	2130	95	1332	2117	1		NA	NA	1.36	.06
20	44	6	100	0	5.17	0.00		12.07	5.70	4.98	7.17	4.20	1.30	4.48	32	930	1920	74	1201	2000	0		NA	NA	.50	0.00
20	45	7	100	0	6.00	0.00			6.20	5.12	7.21	1.97	1.25	5.03	27	1023	1632	239	1100	2041	9		NA	NA	.64	.10
20	40	7	100	0	6.00	0.00	3-4		5.71	6.55	10.20	1.97	2.50	3.21	27	1635	1949	239			31		12.20	10.30	2.22	0.00
22	39	8	0	0	0.00	0.00	2-4	4.92	2.50	6.00	4.00	2.00	1.30	1.20	24	1330	1917	39	1551	1901	99		NA	NA	.79	.17
22	4	11	0	67	.29	5.29		7.55	4.70	1.59	3.62	3.00	.75	3.95	202	1230	1830	161	1317	1922	32	0	7.39	15.30	NA	.65
22	6	14	14	72	1.00	6.83			2.44	2.03	3.75	2.72	.67	1.77	36	1237	1919	78	1427	2003	55		21.90	20.11	.46	.20
23	23	8	0	0	0.00	0.00	3-6	4.60	4.13	1.30	3.09	1.90	2.85	1.20	18	920	1813	13	1150	2012	9		NA	NA	.75	.00
23	24	10	0	0	0.00	.78		5.63	2.58	1.41	3.14	1.97	.94	1.64	25	845	1730	36	1047	1755	81	845	3.50	9.00	.09	.07
23	5	12	0	0	0.00	1.10		3.95	3.14	1.75	3.04	1.77	.57	2.57	20	919	1834	24	1008	1859	25		5.47	11.98	.40	.00
24	19	8	0	0	0.00	0.00	3-4	6.87	1.64	3.93	5.65	3.20	.80	.84	20	635	1750	41	1158	2012	9		NA	NA	1.00	0.00
24	22	11	0	100	0.00	7.14			NA	3.33	6.43	2.74	NA	NA	190	700	1330	204	1047	1755	44	10	NA	NA	.67	.78
24	21	11	0	50	.50	2.00			2.80	4.61	9.42	2.74	1.20	1.60	399	1340	1540	204			8	0	NA	NA	.32	.65
24	18	13	0	100	0.00	7.50		7.57	4.96	4.34	7.36	3.39	1.90	2.98	55	852	1328	105	942	1736	22		6.00	13.10	NA	.42
24	40	13	0	100	.25	9.25		7.57	3.33	3.53	5.44	3.39	1.23	2.10	26	1332	1705	105			13		7.90	19.30	1.27	.10
25	17	8	0	0	0.00	0.00	1-4		8.40	17.43	21.70	6.72	4.10	4.30	49	1229	1820	NA	1233	1846	92		NA	NA	6.02	.36
25	15	11	0	100	0.00	7.50		17.79	5.30	10.87	27.30	6.39	2.15	3.15	272	1145	1545	NA	1045	1636	66	460	7.90	NA	2.04	1.17
25	16	14	0	100	0.00	9.25		8.94	6.91	13.94	20.70	4.91	2.60	4.31	62	1207	1614	NA	1258	1749	39		11.00	11.00	2.69	.31
26	14	8	100	0	4.00	0.00	3-7	8.73	4.97	14.65	16.30	3.40	2.37	2.60	189	945	2242	65	1113	3015	35		NA	NA	3.25	.20
26	25	9	100	100	6.17	4.33		35.00	3.84	11.10	14.20	NA	1.41	2.43	55	1623	2309	87	1518	2742	40		7.10	11.00	1.24	2.00
26	13	10	100	60	7.36	2.60		12.30	5.60	4.13	2.00	4.16	2.49	3.11	88	1045	2045	66	1344	3525	55		.60	7.40	1.69	1.50
26-27	12	8	0	0	0.00	0.00	2-4	8.73	2.32	6.65	8.40	3.40	.93	1.39	NA	2255	1525	85			24		NA	NA	1.30	.42
26-27	11	9	0	0	.50	2.00		35.00	2.93	6.92	10.40	NA	1.20	1.65	55	2215	346	87			35		24.60	34.30	.47	.71
26-27	10	10	0	31	1.20	2.20		12.30	2.03	8.02	10.10	4.16	1.20	1.63	88	2050	1150	66			35		5.00	16.90	1.61	.64
27	9	15	25	100	1.50	6.00	2-4	16.27	3.43	6.85	10.50	4.29	2.03	1.40	32	440	1630	40	752	1634	28		7.10	11.00	1.06	.62

* Percentage of sampling period during which the hourly average wind direction was within 30 deg. of line from source to sampler.

** Wind direction variable for factor analysis. Weighting based on 15 minute average wind direction with respect to source-sampler line. Value of 10 is assigned if the wind direction was within 10 degrees of the line ranging to 0 if the wind direction averaged more than 40 degrees from the line. The weightings for all quarter hour periods through the sampling time are averaged to obtain the final value.

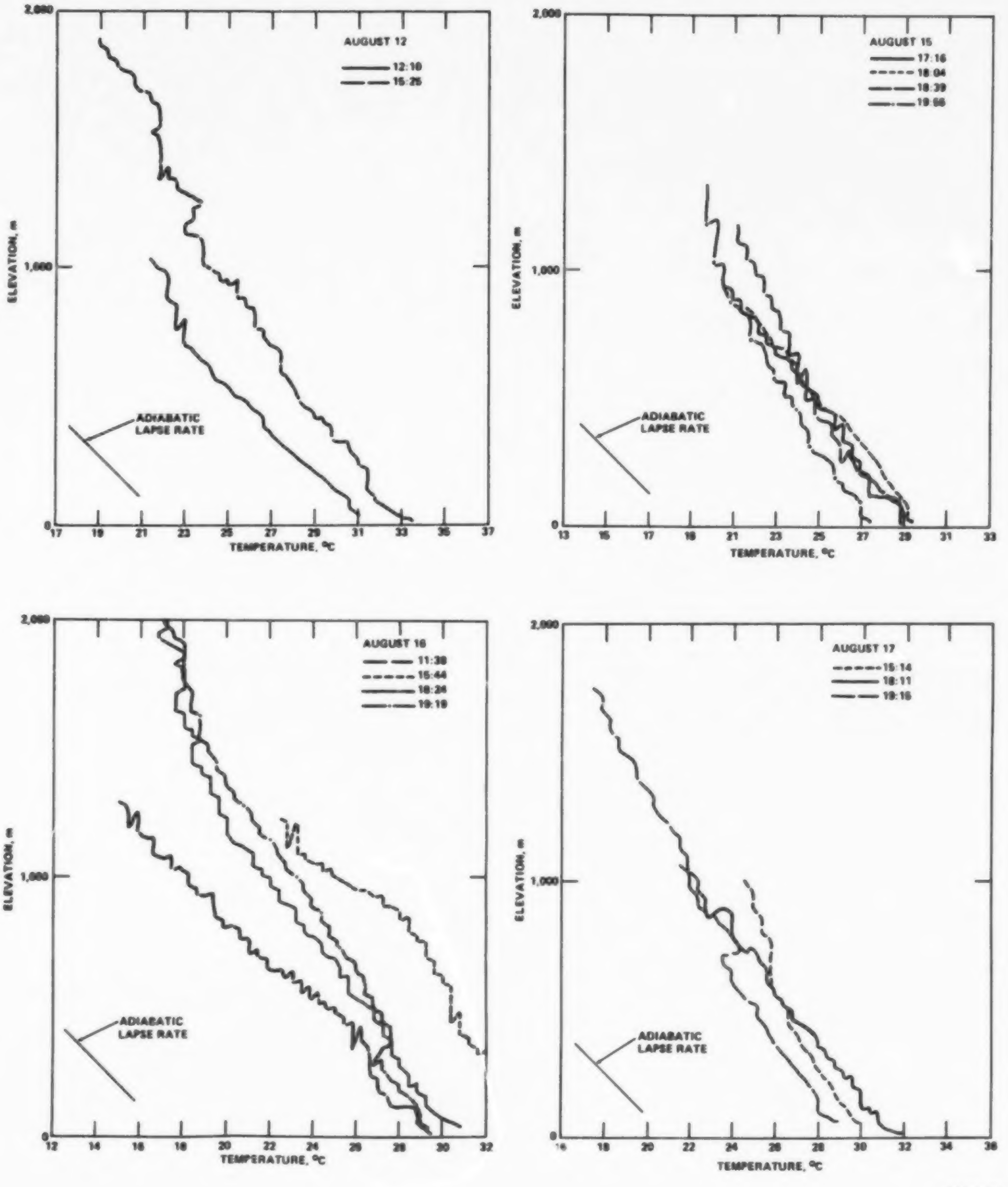


Figure 14. Atmospheric temperature soundings for August 12 through August 17.

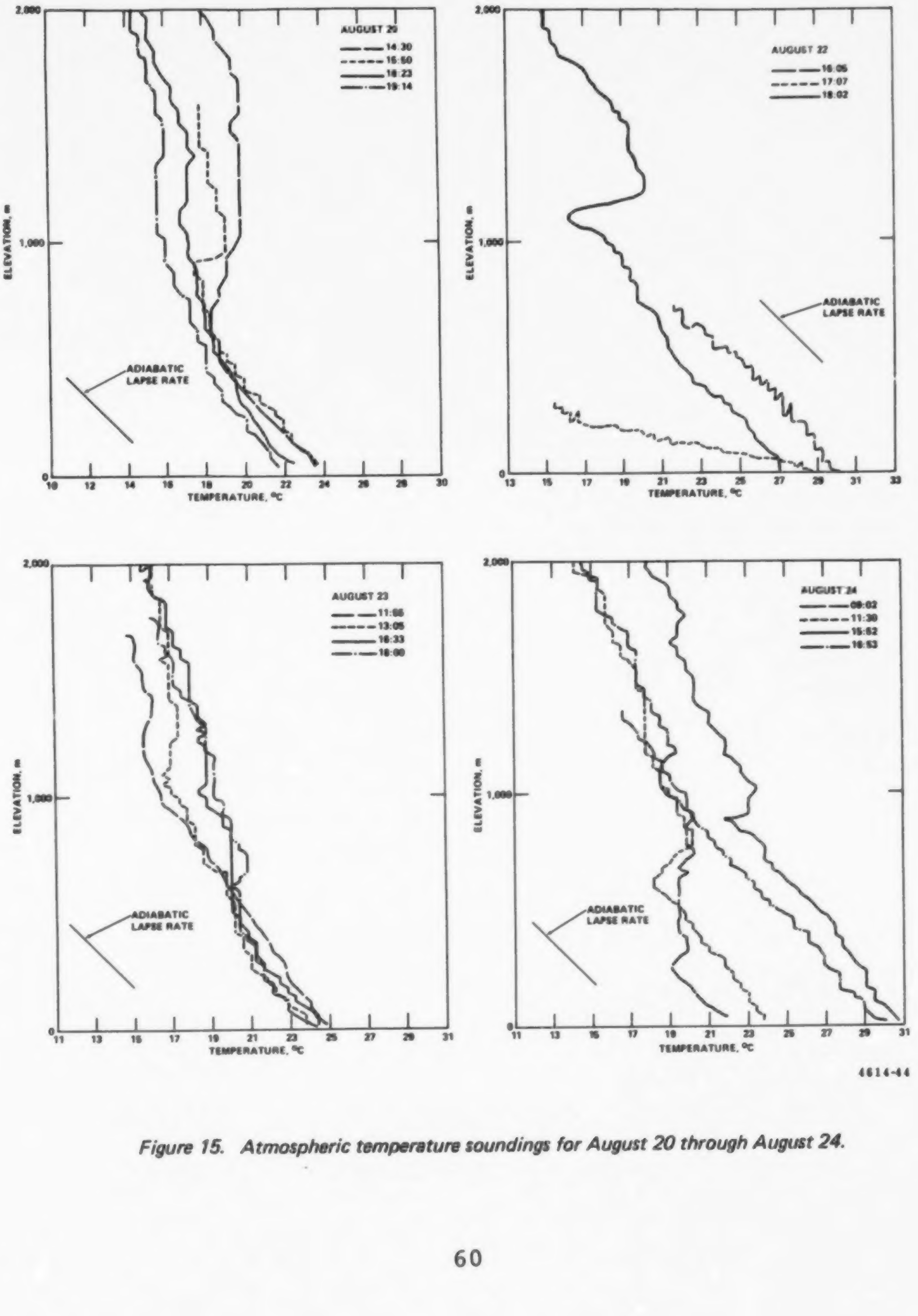


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Figure 15. Atmospheric temperature soundings for August 20 through August 24.

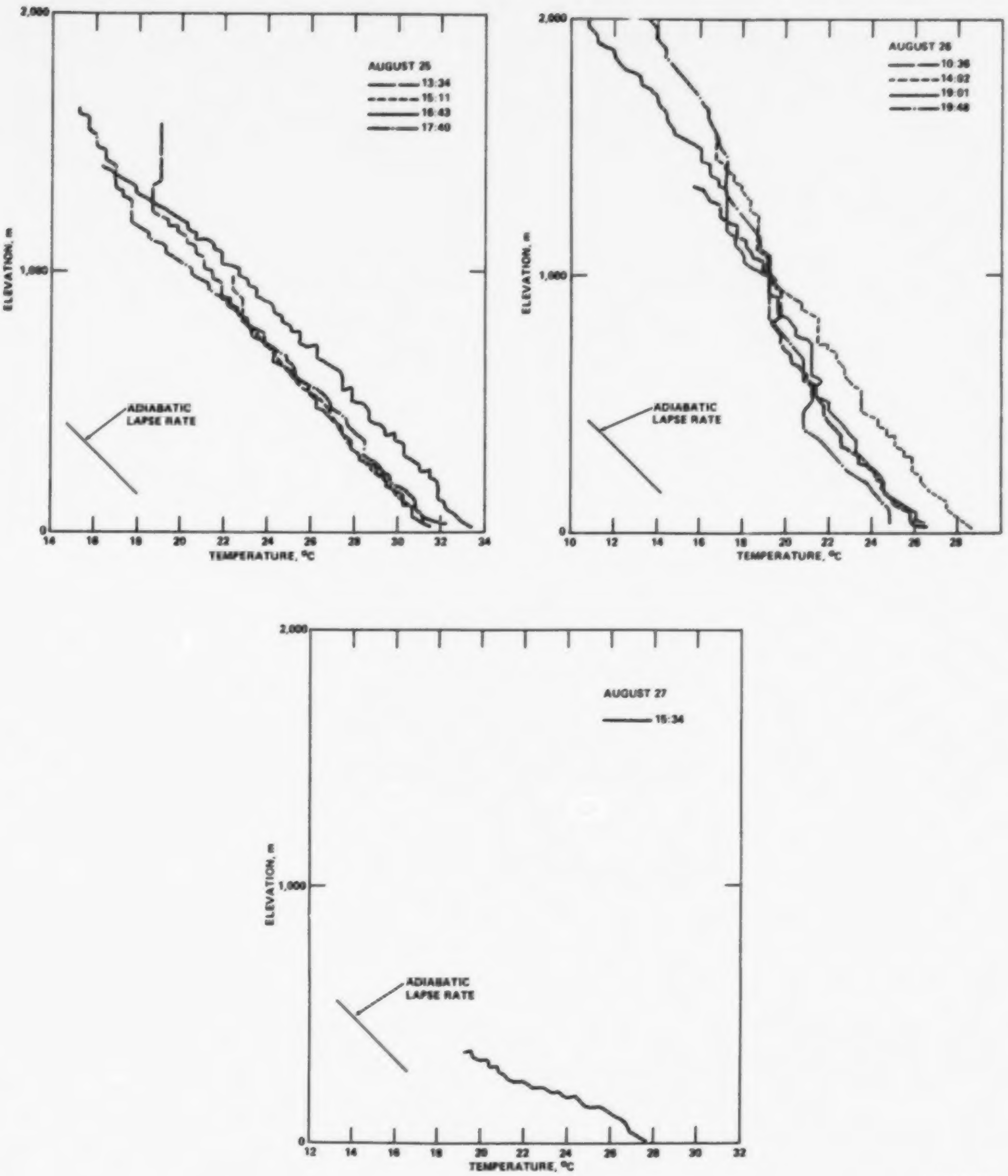

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Figure 16. Atmospheric temperature soundings for August 25 through August 27.

Skies were generally clear with some scattered cumulus in the distance. A seabreeze was expected to set in shortly after noon, so sampling sites were selected with that in mind. Locations 1 and 3 in Figure 2 were used as downwind sites, and site 5 was used for the upwind location.

After setting up the equipment, five of the six continuous analysers were found to be inoperative. The problems were eventually traced to damage caused by shock and vibration in transit to Georgia. In order to increase the mobility of the mobile sampling stations, the instrumentation trailers used in the Phase I study had been abandoned in favor of mounting all the sampling equipment on or in the four-wheel-drive vehicles. The continuous analysers had been bolted directly to heavy plywood sheets that were directly attached to the vehicle frames. No shock and vibration mounts were used, resulting in the instruments sustaining a great deal of abuse in the drive from Connecticut. Therefore on this date, sampling with the remaining techniques and the one working NO_x analyser was carried out.

About 1420 the seabreeze set in, with the wind shifting from WNW to come out of the SSE at 4 to 7 m/s. In the early evening, at approximately 2000, the winds shifted to come out of the south and sampling was ended for the day. Because of personnel being occupied by the malfunctioning instruments, no pilot balloon releases were made on this date. Plots of hourly average wind directions and half-hourly average NO_x concentrations at Site 5 are shown in Figure 17.

Test 2 - 8/12/81

The National Weather Service (NWS) forecast for the day called for light winds from the SSW during the morning with a seabreeze from the SE setting in about 1300-1400, and a 40% chance of thunderstorms in the evening. Site 2 was selected for downwind sampling in anticipation of the seabreeze, and site 5 was again used for the upwind station. Only one downwind station was deployed, as the other was held back for further work on the malfunctioning instrumentation.

The seabreeze did not actually set in until about 1500 and downwind sampling was carried out from then until 1800 when the seabreeze died. Hourly average wind directions through the test day are shown in Figure 18.

Test 3 - 8/15-16/81

Testing was suspended on 8/13 and 8/14 while efforts continued toward repairing and remounting the continuous analysers. On 8/15 it was clear that only one of the SO_2 analysers and two of the NO_x analysers could be made to function reliably at that time. The sampling stations were therefore re-deployed with those

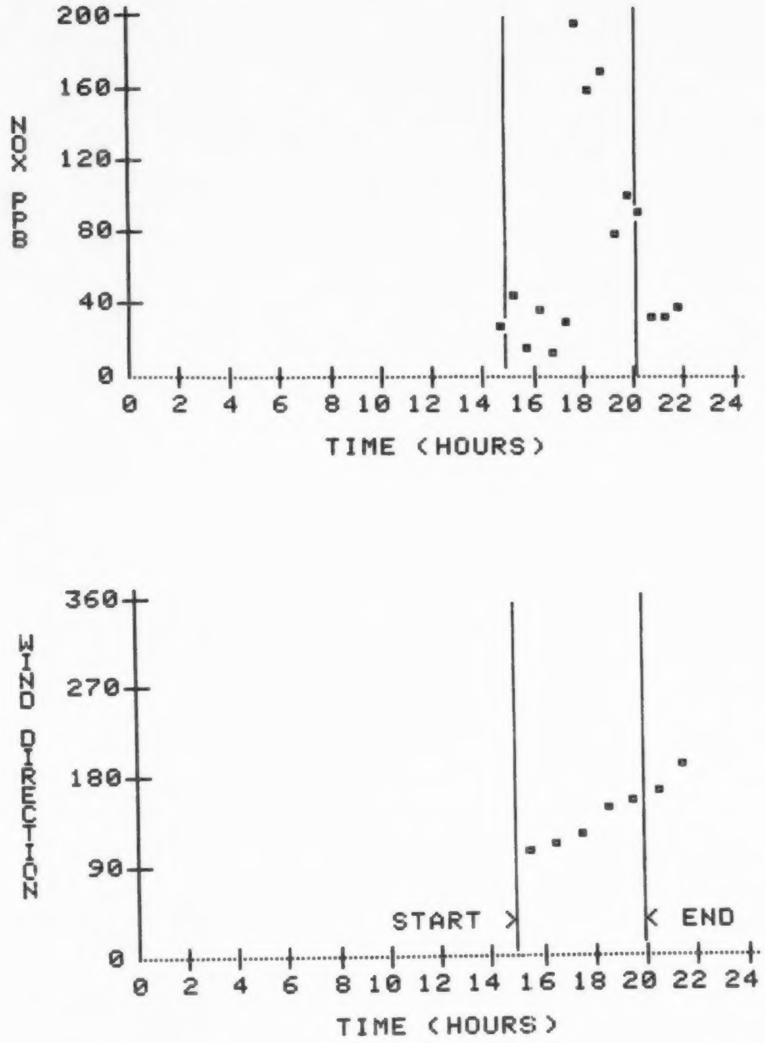

Figure 17. Wind directions and site 5 NO_x concentrations through August 11 test period.

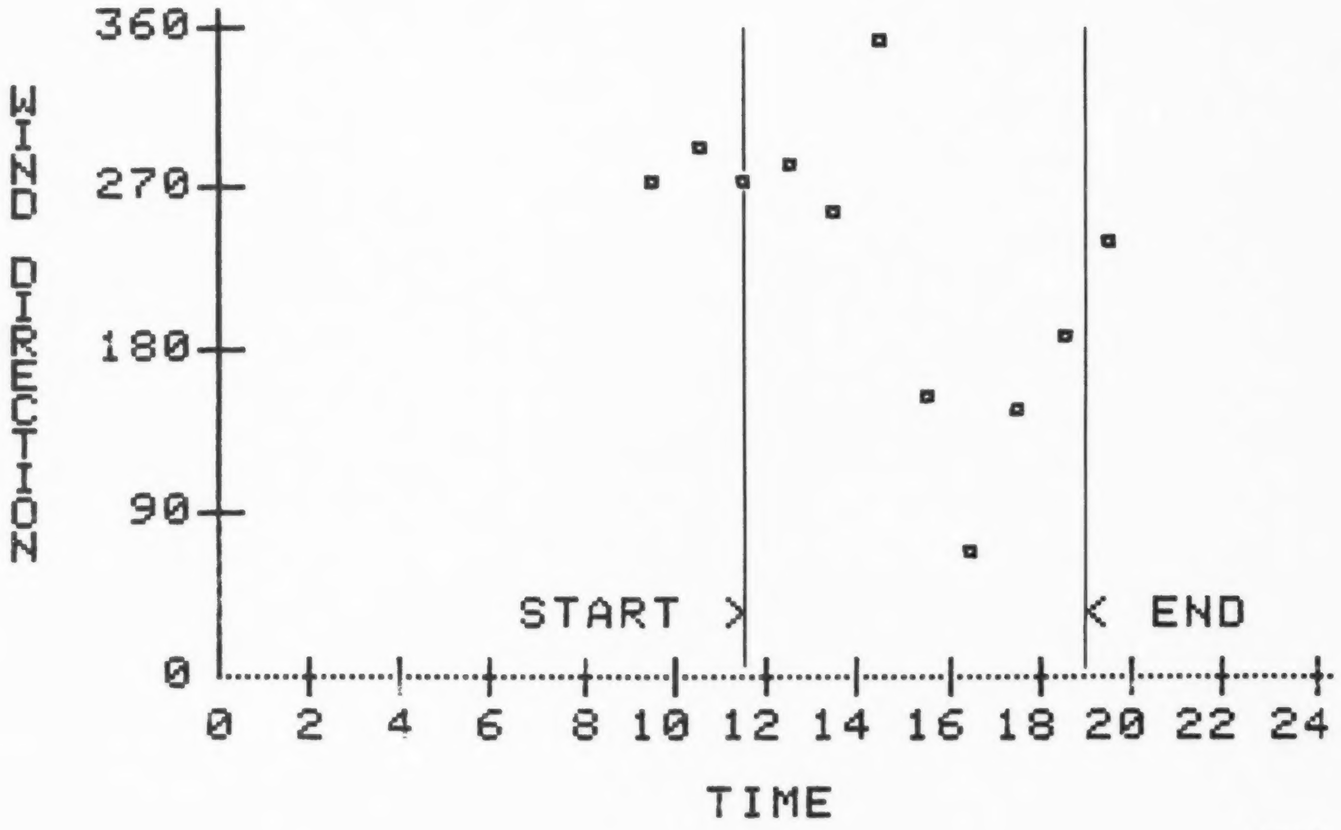

Figure 18. Wind directions through the August 12 test period.

analysers that were serviceable together with the equipment for the other techniques being used.

A high pressure system was located over the eastern Carolinas, resulting in predicted winds from the East and Southeast. With these predicted winds, sites 1 and 4 were selected for use as downwind locations for the 16th. Again, the sites were chosen in anticipation of a seabreeze, as the most persistent winds with regard to direction had been occurring during the times the seabreeze was present.

In order to obtain additional data, the downwind stations were deployed late in the afternoon on 8/15 with a NO_x analyser at one site and TSP and sulfate-nitrate samplers at another for overnight operation. The third mobile station was deployed for use as a nominal upwind location from 0900 to 2015 on the 16th.

Winds were out of the SE and S at 2 to 3 m/s from 1800 through 2400 on the 15th after which they were predominantly from the WSW until 1700 on the 16th. On the 16th the Carolina high had moved off the coast and a high pressure ridge had built up over Eastern Florida, resulting in WSW winds. Hourly average wind directions and half-hourly average SO_2 and NO_x concentrations at Site 3 are illustrated in Figure 19. An area-wide haze occurred on the 16th, accompanied by elevated sulfate concentrations.

Test 4 - 8/16-17/81

The NWS predicted that tropical storm Dennis, located to the SE of the Florida peninsula, would begin to dominate the local weather pattern, resulting in predicted easterly winds by the afternoon of the 17th. The mobile stations at locations 2 and 4 were left in place with the station at location 2 remaining in operation overnight. Sampling was resumed at location 4 at 0930 on the 17th. The third station was not deployed as efforts continued toward placing more of the continuous analysers back in service.

Winds in the late evening hours of the 16th were steady from the south at velocities of 5 to 8 m/s. During the morning hours of the 17th the winds were light and variable from the WSW to N at 2 to 3 m/s. Skies were clear. During the afternoon hours of the 17th winds were from the E and ESE at 4 to 6 m/s. In the early afternoon scattered cumulus clouds began to develop and at about 1800 a line of thunderstorms approached from the N and NW. Sampling was halted for this test with the arrival of the thunderstorms. Hourly average wind directions through the test period are shown in Figure 20a.

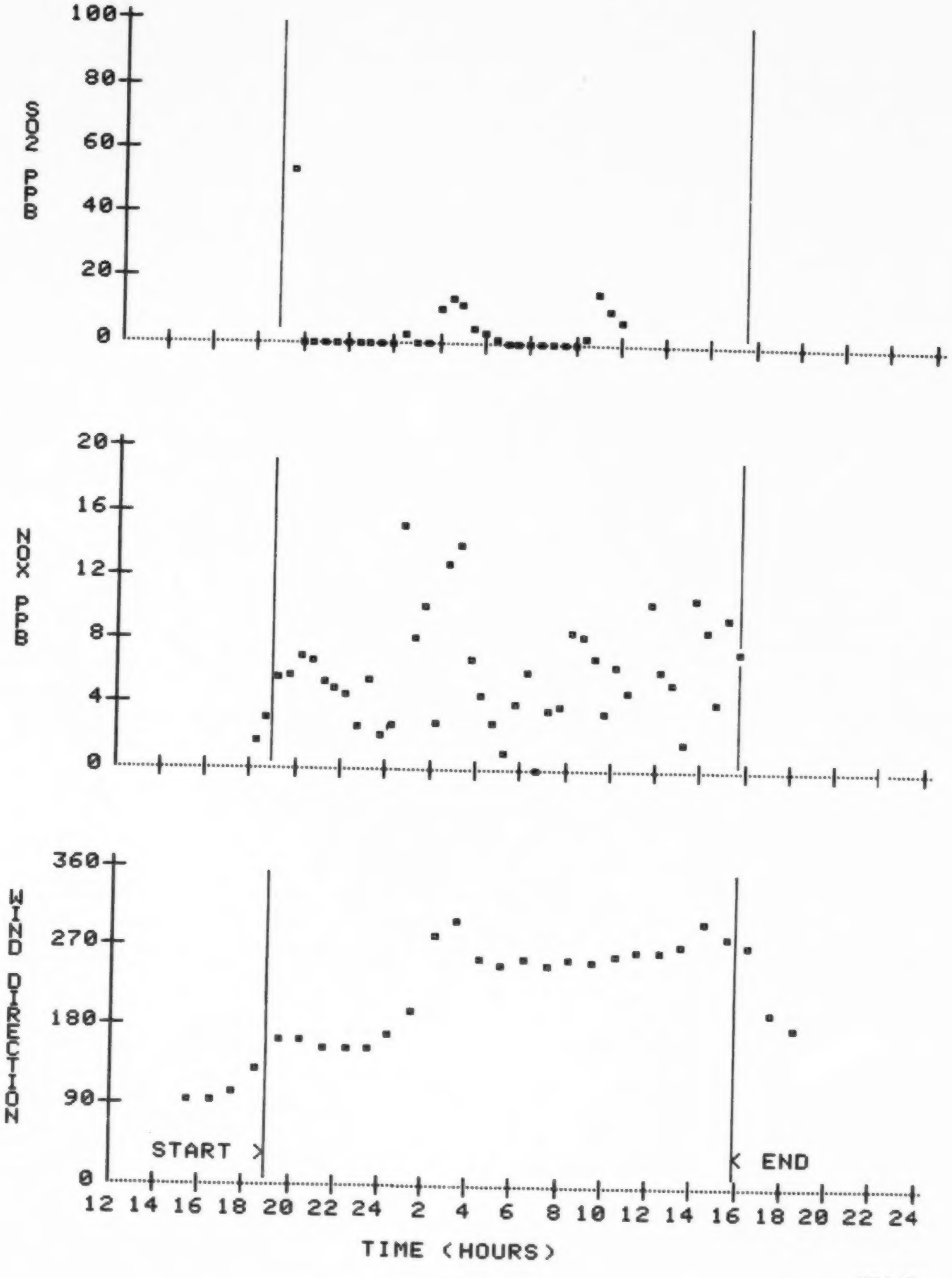

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Figure 19. Wind directions and site 3 SO_2 and NO_x concentrations through the August 15-16 test period.

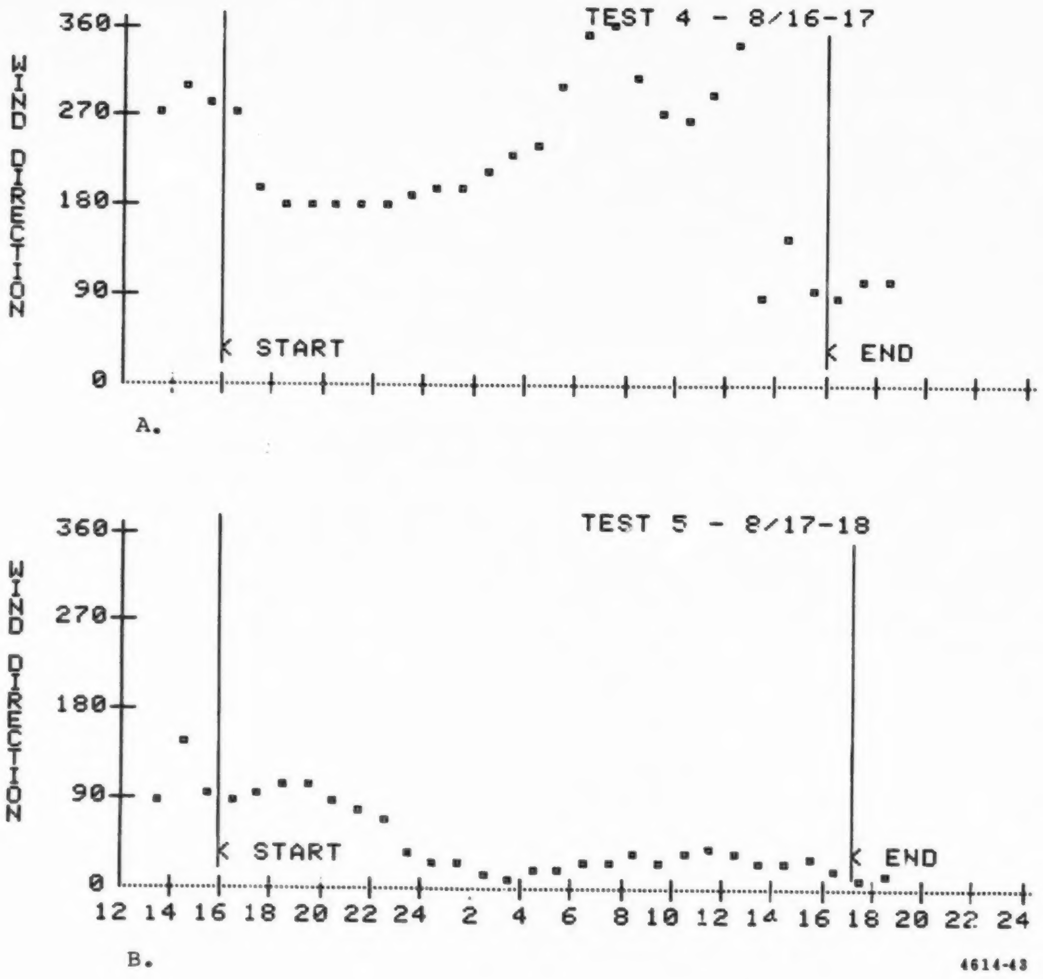

Figure 20. Wind directions through the test periods on August 16-17 and August 17-18.

Test 5 - 8/17-18/81

After the passage of the thunderstorms in the late evening of the 17th, the winds were from the NNE at 5 to 9 m/s. After 0400 on the 18th, the wind velocities became fairly steady with speeds of 7 to 9 m/s from the NNE. Skies remained overcast as the tropical storm approached.

Rain from the thunderstorms left the roadways on the dyke systems too treacherous to move the sampling stations from locations 2 and 4. As the stations were being left in place, they were again left in operation overnight. The sampling was broken off on the morning of the 18th for changes of filters, etc., and restarted shortly, continuing through mid-afternoon of the 18th. Hourly average wind directions through the test are illustrated in Figure 20b.

Test 6 - 8/20/81

Testing was suspended on the 19th as tropical storm Dennis passed off the coast moving NNE. On the 20th, after the storm had passed, northerly winds were predicted for the day with continued overcast skies. The winds did, in fact, persist from the north at 3 to 5 m/s throughout the day. Site 5 was again used as a nominal upwind location and Sites 6 and 7 were used for the downwind stations. Sampling proceeded at these locations from about 1000 through 2000. Hourly average wind directions and NO_x concentrations at Site 7 are illustrated in Figure 21.

This sampling concluded the ambient sampling in the immediate vicinity of the acid plant.

Test 7 - 8/22/81

At this time, the selection of test locations was changed to emphasize sites in the vicinity of the pulp mill. On this date winds were out of the north at speeds of about 3 m/s through the morning and mid-day hours, hence Sites 11 and 14 were selected as downwind locations and Site 8 for the upwind station. The skies were mostly cloudy throughout the day, with the cloud cover ranging from 60 to 80 percent. Sampling took place from about 1230 through 1900, although the winds shifted to come from the northeast at about 1400 reducing the probability of any plume impact from the pulp mill after that time. Hourly average wind directions for this date together with half-hourly average NO_x concentrations at the two downwind sites are shown in Figure 22.

Test 8 - 8/23/81

The forecast called for light to moderate winds from the ENE, so sites 10 and 12 were selected for the downwind locations. Site 8 was used again for the upwind sampling station. The cloud cover

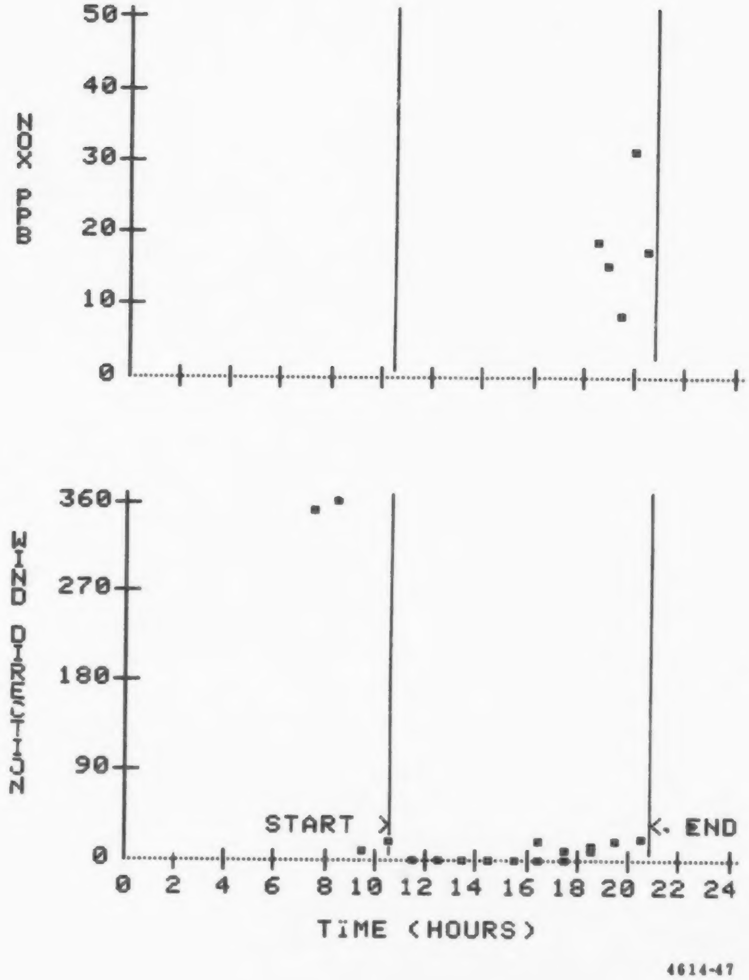

Figure 21. Wind directions and site 7 NO_X concentrations on August 20.

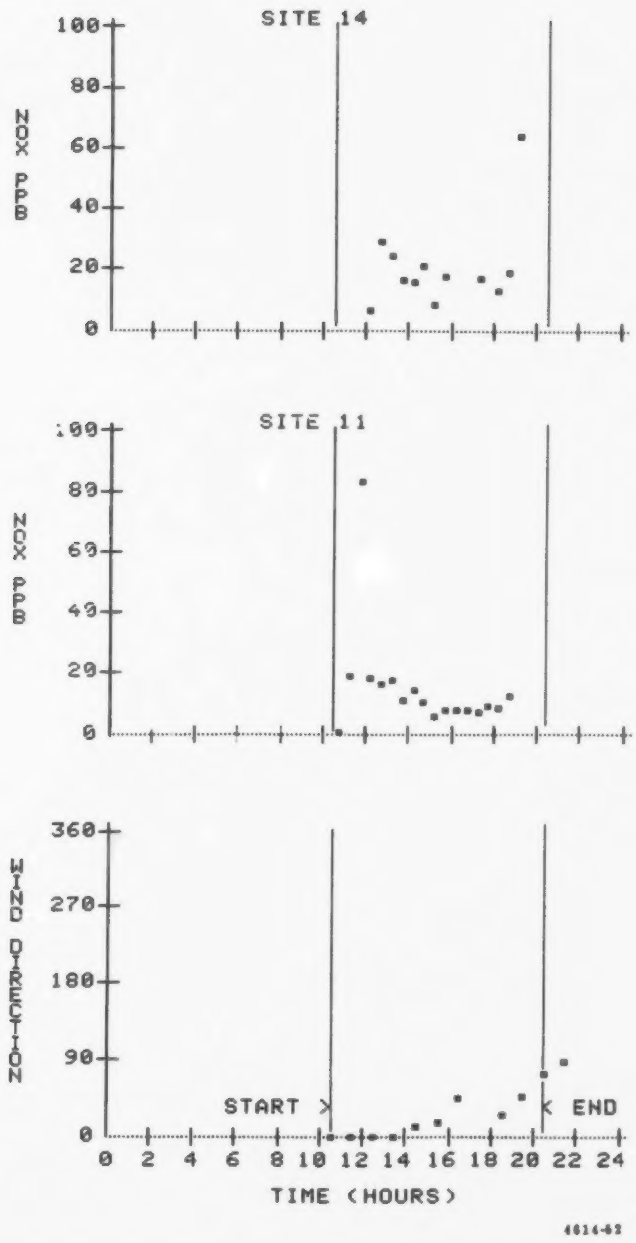

Figure 22. Wind directions and sites 11 and 14 NO_X concentrations for the August 22 test period.

was 100 percent from morning through the early afternoon with light, intermittent rain through most of the day. Pilot balloon tracking in the early afternoon indicated that the downwind sites were located directly along the lines of travel of the plumes from the pulp and paper plant. Wind speeds were in the 2.5 to 5 m/s range through the test period, which began about 0930 and ended at about 1830. Surface winds during the test period were out of the NNE to N. Hourly average wind directions and half-hourly average NO_x concentrations at the two downwind sites are illustrated in Figure 23.

Test 9 - 8/24/81

The forecast called for winds out of the NE and E for the night of the 23rd and 24th and on through the day on the 24th. However, the observed winds on the morning of the 24th were out of the north, so sites 11 and 13 were selected for the downwind stations. Site 8 remained in use as the upwind location. The skies were mostly clear with scattered clouds (cloud cover = 10%), and wind speeds were consistent through the day at about 4 m/s. Plume impact was definitely noted (by odor) at times at site 13. Sampling began about 0800 and ended about 1700 when a seabreeze caused a wind shift to the SSE. Figure 24 shows hourly average wind directions and NO_x concentrations at site 13 through the test period.

Test 10 - 8/25/81

During the morning hours the winds were calm, with such winds as there were meandering from the W and NW. At mid-morning the wind speed picked up and the direction seemed to stabilize out of the north, so sites 11 and 14 were selected again for the downwind stations and site 8 for the upwind location. Skies were clear, but quite hazy throughout the region. Sampling took place from about 1200 to 1600. Sampling ceased when it appeared that a seabreeze was imminent, as it would result in a reversal of the surface winds. Figure 25 illustrates average wind directions through the test day together with NO_x concentrations at site 14. The maximum sulfate and nitrate concentrations of the entire test program were observed on this date.

Test 11 - 8/26/81

On this date the winds were out of the ENE at 5 to 7 m/s. A high pressure cell located to the north made it likely that the winds would remain out of that direction, or perhaps veer around from the East. Skies were hazy with 20% cumulus cloud cover. Sites 8, 9, and 10 were selected, with 8 again used as the upwind location. Downwind sampling took place from about 1000 to 2200. NO_x concentrations at the downwind sites and hourly average wind directions are illustrated in Figure 26. Again the measurement results showed high sulfate and nitrate concentrations.

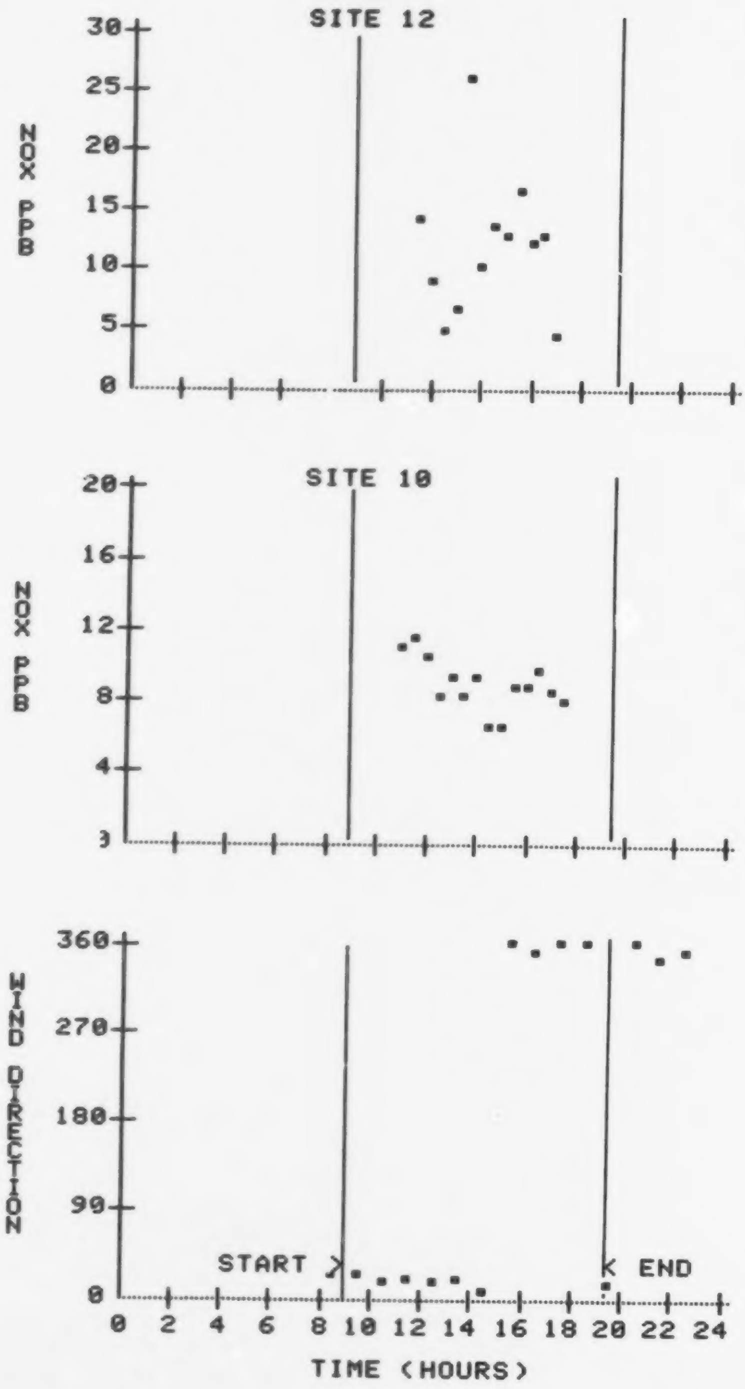

Figure 23. Wind directions and sites 10 and 12 NO_x concentrations for the August 23 test period.

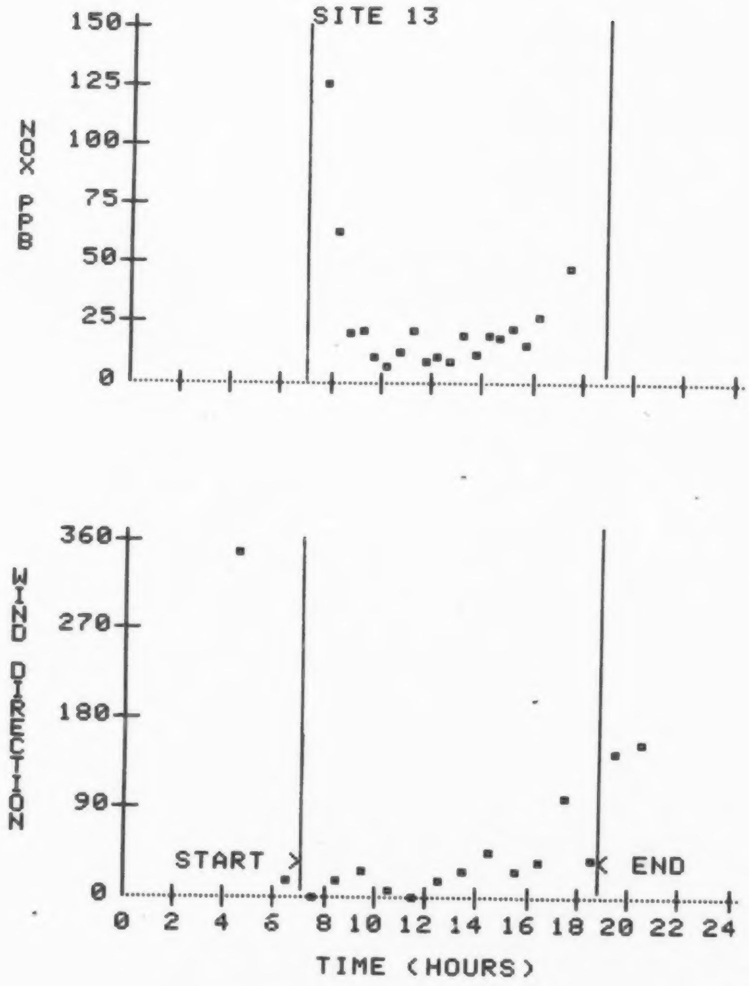

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Figure 24. Wind directions and site 13 NO_X concentrations for the August 24 test period.

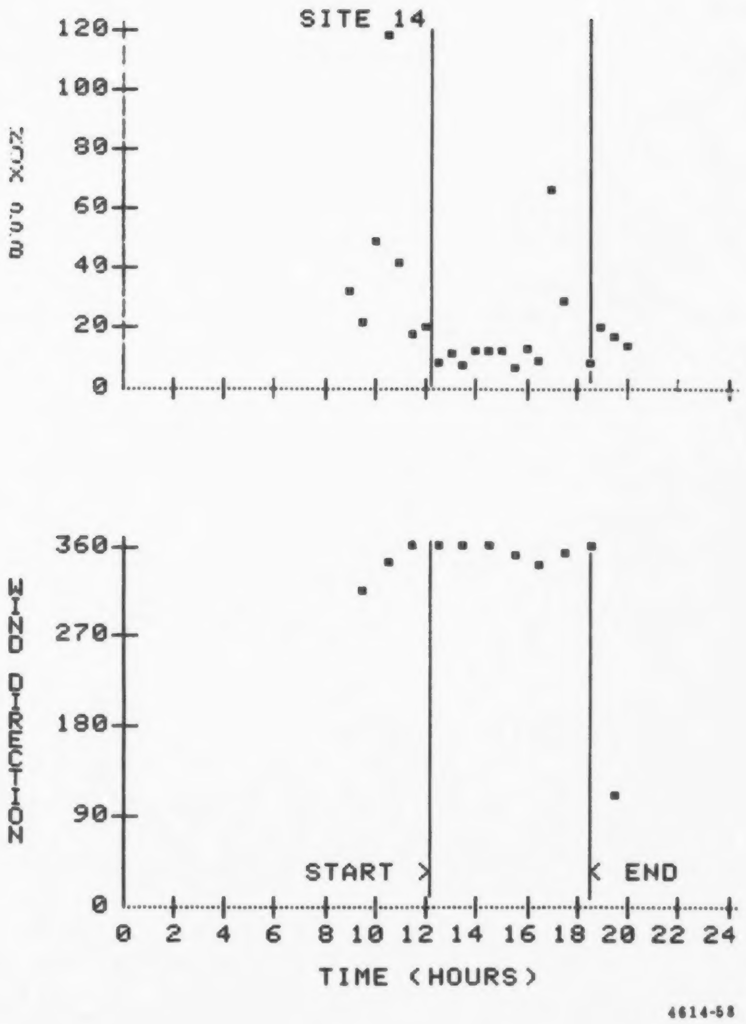

Figure 25. Wind directions and site 14 NO_x concentrations for the August 25 test period.

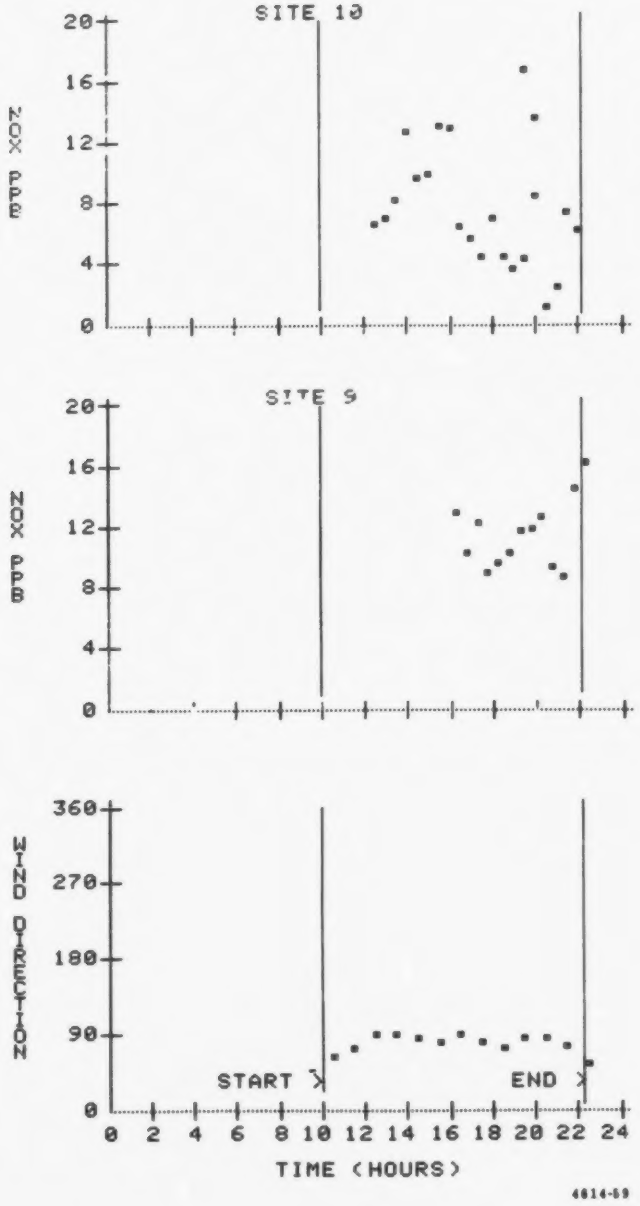

Figure 26. Wind directions and sites 9 and 10 NO_x concentrations for the August 26 test period.

Test 12 8/26-27/81

In part this test continued test 11, with the stations at sites 8 and 10 remaining in place and a change of filters being made. The station at location 9 was moved to site 15. Winds were out of the NE at speeds of 2 to 5 m/s in the early hours of the test and continued from that direction with some increase in speed as the day progressed. Scattered cirrus clouds were present early on, and by mid-morning the skies were mostly overcast with stratocumulus clouds. Sampling took place from about 2200 on the 26th to 1600 on the 27th. NO_x concentrations at the downwind sites and hourly average wind directions are illustrated in Figure 27. The haze noted during the previous two days appeared to have dissipated, and the sulfate and nitrate concentrations were down substantially.

SO_2 measurement results

Two methods of measuring ambient SO_2 concentrations were employed: continuous monitors and peroxide bubblers. The primary data were to be taken with the Meloy analysers, while time integrated samples were to be taken coincident with each sulfuric acid sample to permit better estimates of sulfate and sulfuric acid ratios to SO_2 to be made than were possible from integration of the continuous analyser recorder charts. Problems were encountered with each method that in the end resulted in significant loss of data.

In the case of the Meloy continuous analysers, the mechanical and chemical damages described earlier resulted in only one SO_2 analyser remaining in service throughout most of the test program. At the time, the loss of the other two did not appear to be critical because of parallel measurements of SO_2 which were being made in conjunction with the operation of the sulfuric acid samplers. The limited data obtained with the continuous analyser is summarized in Table 19, which also includes a summary of the results obtained with the NO_x analysers. When the instantaneous SO_2 concentrations were compared with wind directions, the concentration peaks did not appear to occur when the sources of interest were upwind of the sampling locations, indicating that the target sources were not the most significant SO_2 emitters in the area.

With the failures of the SO_2 analysers, the peroxide bubblers became the primary SO_2 measurement technique. However, the bubbler field blanks showed high sulfate backgrounds, making the interpretation of the data obtained with them subject to question. The data, after blank corrections, are tabulated in Appendix D and summarized in Table 18. These results are subject to large uncertainties because of the high blanks.

TABLE 19. MEASURED AMBIENT SO_2, NO, NO_x CONCENTRATIONS: CONTINUOUS ANALYSER DATA

		Measured Ambient Concentrations								
		SO_2			NO			NO_x		
Date	Site	Start Time	End Time	Average for Period (ppm)	Start Time	End Time	Average for Period (ppm)	Start Time	End Time	Average for Period (ppm)
8/11/81	1			DNR			DNR			DNR
8/11/81	3			DNR			DNR			DNR
8/11/81	5			DNR	1430	1100 (8/12)	15.002	1430	1100 (8/12)	85.440
8/12/81	3			DNR			DNR			DNR
8/12/81	5			DNR			DNR			DNR
8/15/81	2			DNR			DNR			DNR
8/15/81	4	1730	1015 (8/16)	4.504			DNR	1800	1600 (8/16)	6.333
8/16/81	2			DNR			DNR	--------See 8/16--------		
8/16/81	5			DNR			DNR			DNR
8/17/81	2			DNR			DNR			DNR
8/17/81	4			DNR			DNR			DNR
8/18/81	2			DNR			DNR			DNR
8/18/81	4			DNR			DNR			DNR
8/18/81	5			DNR			DNR			DNR
8/20/81	7			DNR	1815	2030	12.191	1815	2030	18.348
8/20/81	6			DNR			DNR			DNR
8/20/81	5			DNR			DNR			DNR
8/22/81	14			DNR	1200	1930	21.852	1200	1930	20.113
8/22/81	11	1230	1830	0.0	1030	1700	7.390	1030	1700	15.377
8/22/81	8			DNR			DNR			DNR

(continued)

TABLE 19 (continued)

		Measured Ambient Concentrations								
		SO$_2$			NO			NO$_x$		
Date	Site	Start Time	End Time	Average for Period (ppm)	Start Time	End Time	Average for Period (ppm)	Start Time	End Time	Average for Period (ppm)
8/23/81	10			DNR	1115	1715	5.466	1115	1715	11.983
8/23/81	12	1230	1730	0.845	1045	1745	3.498	1045	1745	8.996
8/23/81	8			DNR			DNR			DNR
8/24/81	13			DNR	0730	1800	13.623	0730	1800	26.884
8/24/81	11	0800	1800	4.757	--------Data Void - Heavy Equipment in Area--------					
8/24/81	8			DNR			DNR			DNR
8/25/81	14			DNR	0815	2300	19.954	0815	2300	25.195
8/25/81	11	1145	1700	0.352	1400	1000 (8/26)	15.753			DNR
8/25/81	8			DNR			DNR			DNR
8/26/81	9			DNR	1600	1530 (8/27)	11.058	1600	1530 (8/27)	17.020
8/26/81	10			DNR	1215	1030 (8/27)	2.966	1215	1030 (8/27)	12.934
8/26/81	8			DNR			DNR			DNR
8/27/81	15			DNR	--------See 8/26--------			--------See 8/26--------		
8/27/81	10			DNR	--------See 8/26--------			--------See 8/26--------		
8/27/81	8			DNR			DNR			DNR

DNR - Did not run

NO_x measurement results

Summaries of the ambient NO_x data was included in Tables 18 and 19. The summaries in Table 18 cover only the periods when filter samples were being taken, while those in 19 include all hours of NO_x analyser operation. High ambient NO_x concentrations showed essentially no correlation with occasions when the sources of interest were located upwind of the sampling stations. Data for individual sites and days were shown in Figures 17 through 27. In some cases concentration peaks were noted which, judging by the wind direction, probably represented the impact of the plume from the Savannah G&E Port Wentworth power station. No verifiable NO_x impacts from either the Cyanamid or Union Camp plants were observed, a not unexpected result given the relatively low emission rates of the sources.

A composite of all NO_x data in terms of average observed concentration over fifteen (15) minute intervals for all locations and all days versus time of day is shown in Figure 28. The data, when plotted in this fashion, indicate that automotive traffic was probably the major contributor to ambient NO_x, as the major concentration peaks tend to coincide with peak commuting and luncheon hours.

Sulfate and sulfuric acid measurements

The results of all ambient sulfate and sulfuric acid sampling were given in Table 18. The values reported on each line of the table are for samples that were taken over approximately the same time intervals; however, they seldom represent truly coincident samples. In a few cases, samples obtained using one method overlapped two samples taken with another; in these cases the entry for the longer duration sample is duplicated for each of the shorter samples. The results reported for the hi-vol samplers were obtained by sulfate ion chromatography of extracts from the teflon membrane filters. The results tabulated for the Lundgren impactors were obtained by summing sulfur concentrations for each impactor stage determined by X-ray fluorescence and assuming that the sulfur was entirely in the form of sulfates. The total sulfate concentrations reported for the acid system samples are the sum of the sulfate found on the particulate filter and that from the "acid filter" (the reagent treated filter used to collect the vaporized acid). These were determined by ion chromatography of extracts of the respective filters.

Regression analysis of the sulfur concentrations from the x-ray fluorescence analyses of the teflon hi-vol filters and the sulfur from the sulfate analyses showed a correlation coefficient of 0.94 with the CSI XRF values systematically high by 40%. A scatter plot comparing the results of the two analyses is shown in Figure 29. The CSI values were also high by a similar amount in

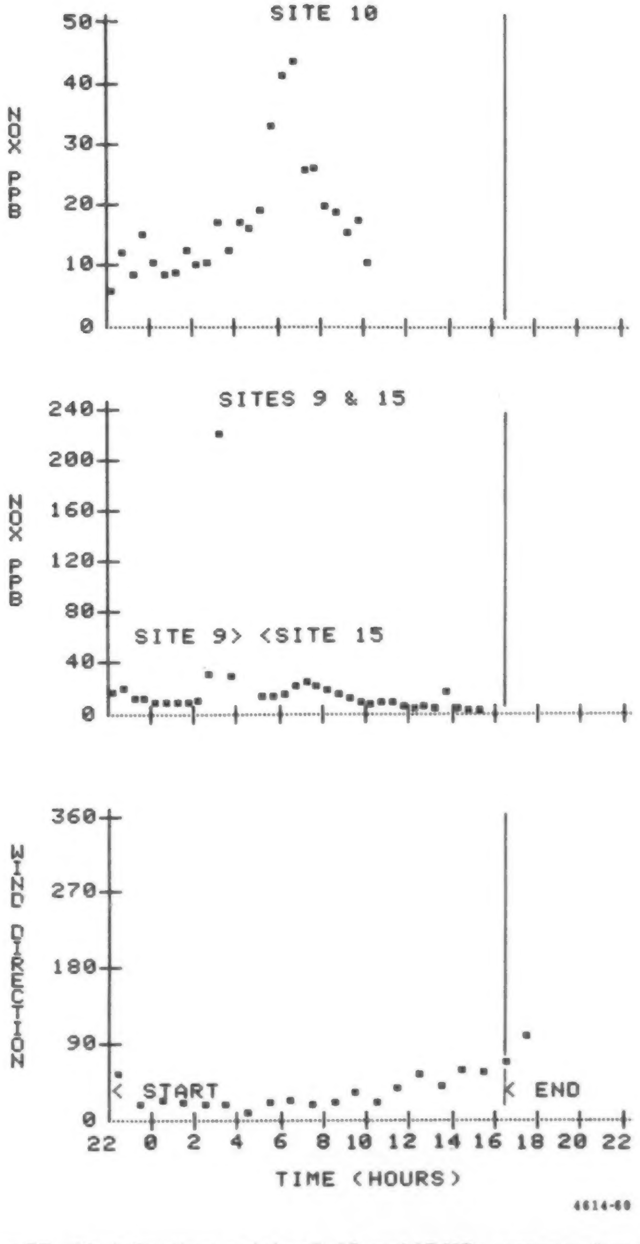

Figure 27. Wind directions and sites 9, 10, and 15 NO_X concentrations for the August 26-27 test period.

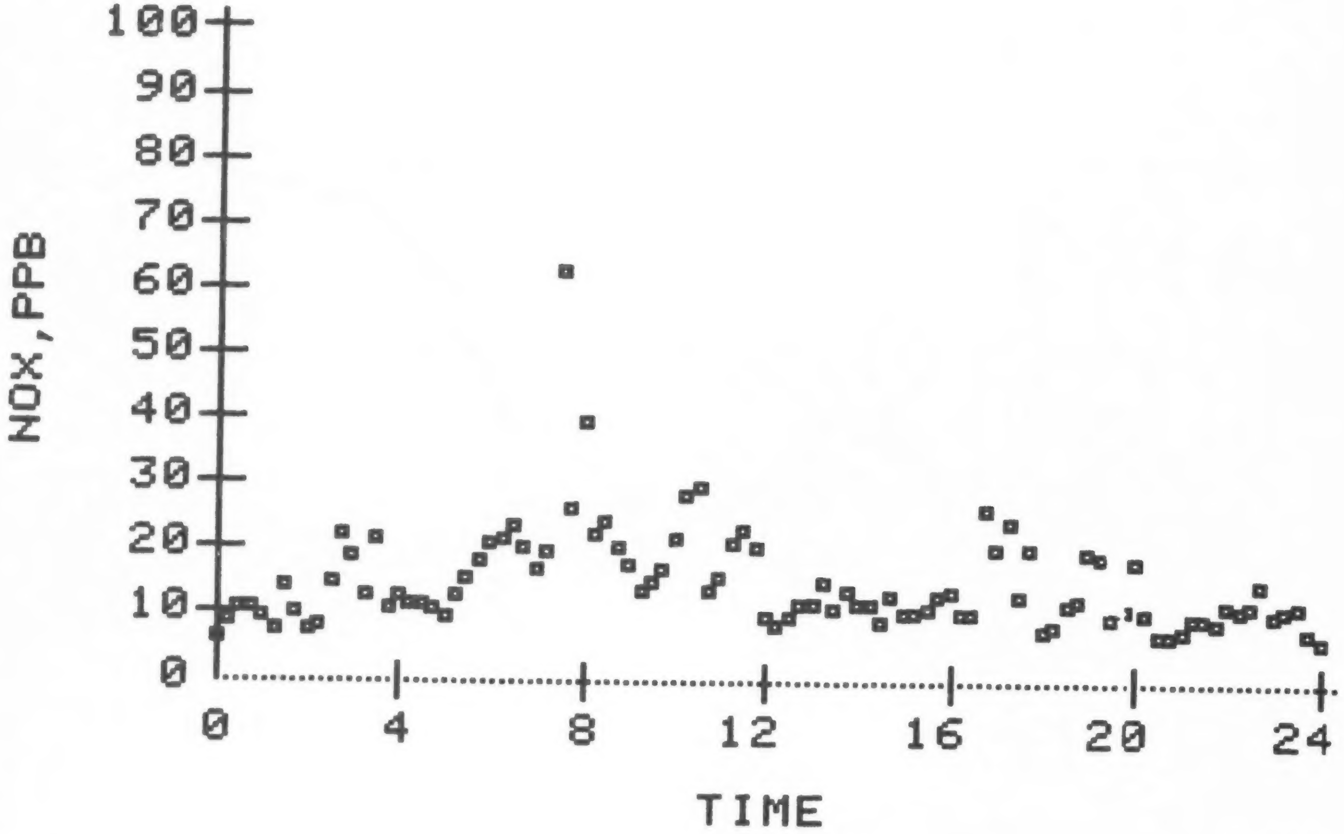

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Figure 28. *Average diurnal variation in NO_x concentrations through the entire test (August 11-August 27).*

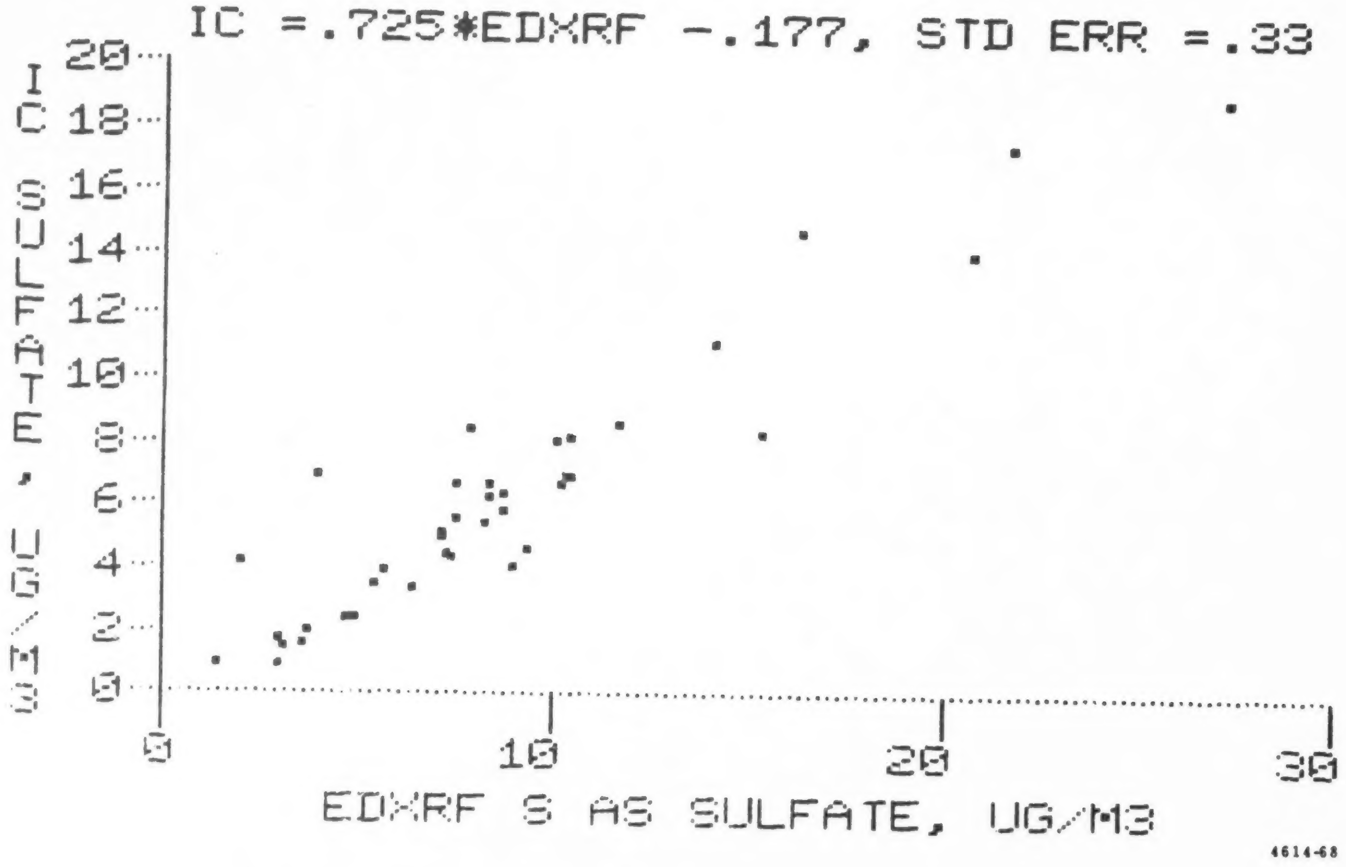

Figure 29. Comparison of ambient sulfate concentrations from Teflon Hi-vol filters by EDXRF analysis and ion chromatography.

comparison to other XRF analyses which were performed by the EPA Environmental Sciences Research Laboratory at Research Triangle Park as illustrated in Figure 30. The CSI values reported here are based on the numbers as received and have not been corrected for the apparent discrepancy.

Regressions of the Lundgren impactor sulfur concentrations (as sulfate) with those from the hi-vols showed that the impactor derived concentrations had a positive bias of about 2.5 $\mu g/m^3$ as compared to the hi-vols. The bias may have been the result of underestimating a background correction required in handling the data from the impactor substrates. A scatter plot of the data from the two methods is shown in Figure 31 together with the least-squares regression line.

In comparing the results from the acid system with those of the other methods, one should keep in mind that only those particles which are aerodynamically smaller than about two micrometers (2 μm) in diameter are passed to the acid system, and some losses occur in the system. The small cut-off diameter and the further losses should always result in the acid system total sulfate concentrations being lower than those determined using the other techniques. Laboratory tests of the acid system showed 85% recovery of submicron H_2SO_4 aerosols as sulfuric acid. The values reported in Figure 29 are as measured, hence the acid component should be increased by about 18% to account for losses. Comparisons of average H_2SO_4 concentrations (after correction for losses) with total sulfate concentrations from the hi-vol samples show that about 60% of the sulfate found in the vicinity of the acid plant complex, both upwind and downwind, was sulfuric acid. Only about 30% of the sulfate was sulfuric acid upwind of the pulp mill while about 50% was sulfuric acid in the downwind samples. The percentages for the pulp mill samples were strongly influenced by data obtained during the very high total sulfate concentration episodes which occurred area-wide on 8/25-26. If the data from these dates are omitted, the pulp mill percentages become 30% and 65%, respectively.

The peak sulfate and nitrate concentrations were measured on days when pervasive, region-wide hazes occurred. These were days when the winds were from the north and west. Because the upwind concentrations were as great as the downwind, even though there were virtually no local sources upwind in those directions, moderate and long range transport must be considered as real possibilities as sources.

Particulate concentrations and size distributions

The primary technique used for determining particle concentrations and size distributions in the ambient was by means of hi-vol samplers equipped with Sierra Model 234 impactor heads. The impaction heads provide size fractionation at aerodynamic

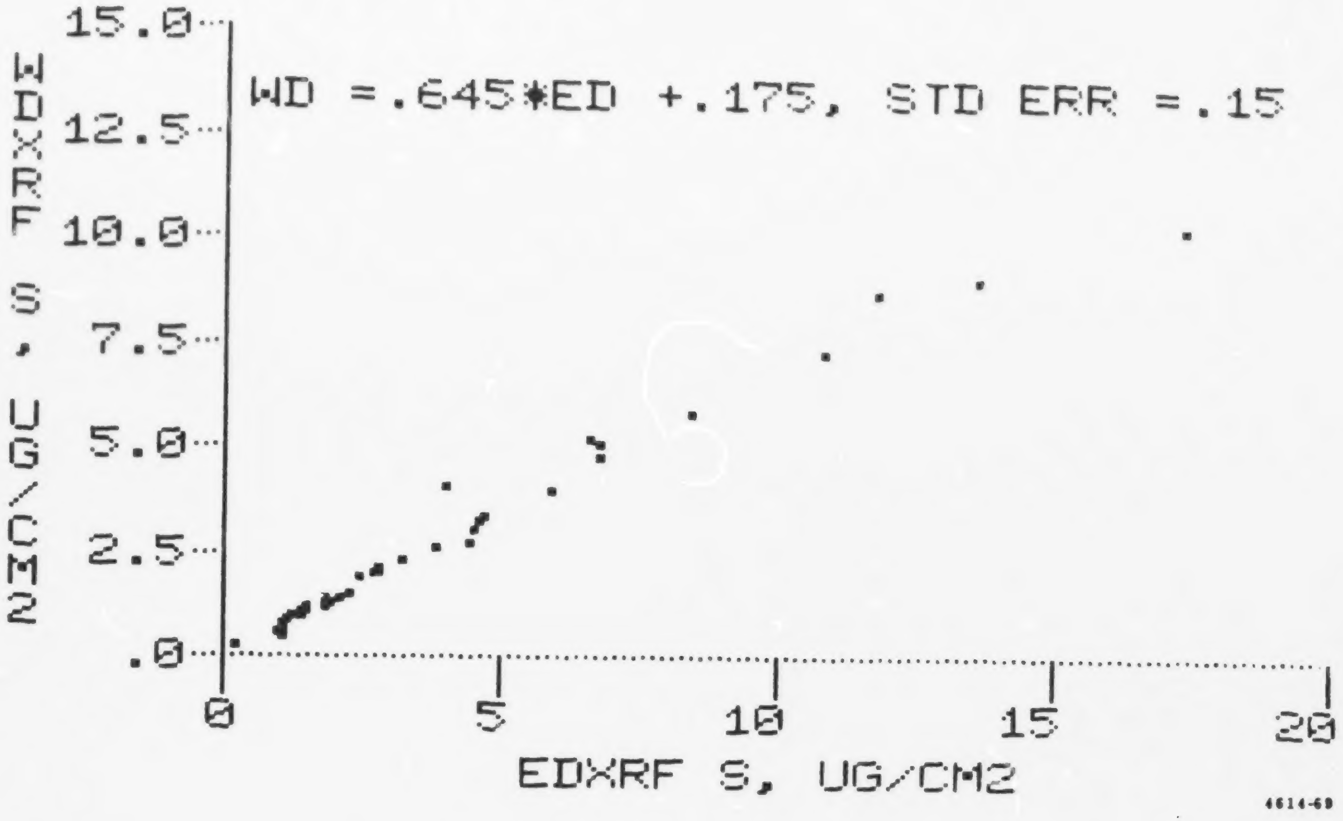

Figure 30. Comparison of Teflon ambient Hi-vol filter sulfur loadings as measured by EDXRF and WDXRF.

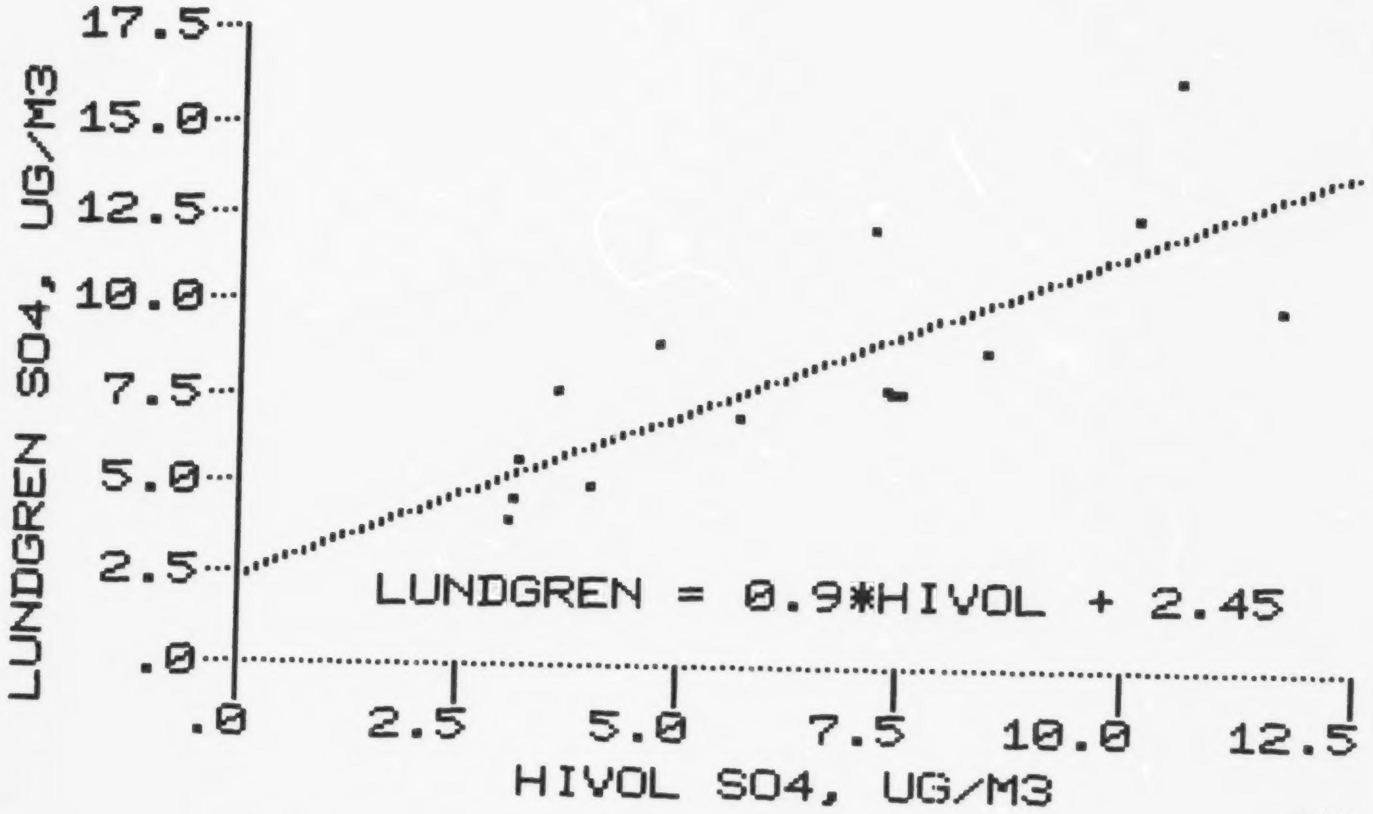

Figure 31. Comparison of ambient sulfate concentrations as measured by Lundgren cascade impactors and Hi-vol samplers.

diameters of 7.2, 3, 1.5, and 0.95 micrometers (μm) at the design flow rate of 1.13 cubic meters per minute (40 cfm). In addition, Lundgren cascade impactors were run to obtain samples for the determination of elemental composition by particle size to aid in isolating particulate sources; however, gravimetric concentration data were also obtained with them. The Lundgren samplers operated at flow rates of 0.113 m^3/min (4 cfm) and provided size fractionation at aerodynamic diameters of 10, 3, 1, and 0.3 μm.

Particulate concentrations as measured by each technique were given in Table 18. In the table, the results of runs which were reasonably coincident in time are given on the same line. In some instances, the Lundgren samplers were set up with their inlets much closer to ground level than those of the hi-vol samplers. On those occasions, the concentrations measured with the Lundgrens were substantially greater than those from the hi-vols. A scatter diagram of the concentrations as measured by the two techniques for near simultaneous runs is shown in Figure 32. The figure indicates that the Lundgren concentrations are biased high by about 20%, and the data showed a scatter of about 30%. The bias may have resulted, in part, from the catches on the hi-vol impactor substrates being below detection limits in almost all cases (101 of 136 substrates) in addition to differences attributable to different inlet heights. The hi-vol filter catch was below the detection limit in only one of thirty-four runs.

Particle size distributions based on the gravimetric analyses are shown in Figures 33, 34, and 35. The size distribution data are also given in tabular fashion in Appendix D2. Figure 33 illustrates the distributions as determined from the hi-vol runs for which an adequate number of stages, aside from the filter, had detectable weight gains. The distributions as measured with the Lundgren impactors are illustrated in Figure 34 for the sampling done in the vicinity of the acid plant. Those from the vicinity of the pulp mill are shown in Figure 35. The distributions measured with the hi-vol impactors all resulted in aerodynamic mass median diameters (MMD's) smaller than two micrometers (2 μm) while the MMD's determined from the Lundgren data ranged from 0.8 μm to 7 μm in the vicinity of the pulp mill and 1 μm 3 μm in the vicinity of the acid plant. The generally smaller median diameters found in the hi-vol results probably result from two causes - first, the missing values from weight gains below detection limits; and second, a bias due to particle bounce that is known to exist with the ambient hi-vol impactor. The particle bounce effect was mitigated in the Lundgren sampling by using a very sticky polymeric coating on the collection substrates to aid in the retention of particles which contact the surfaces and by collecting a mono-layer or less of particles on the substrates.

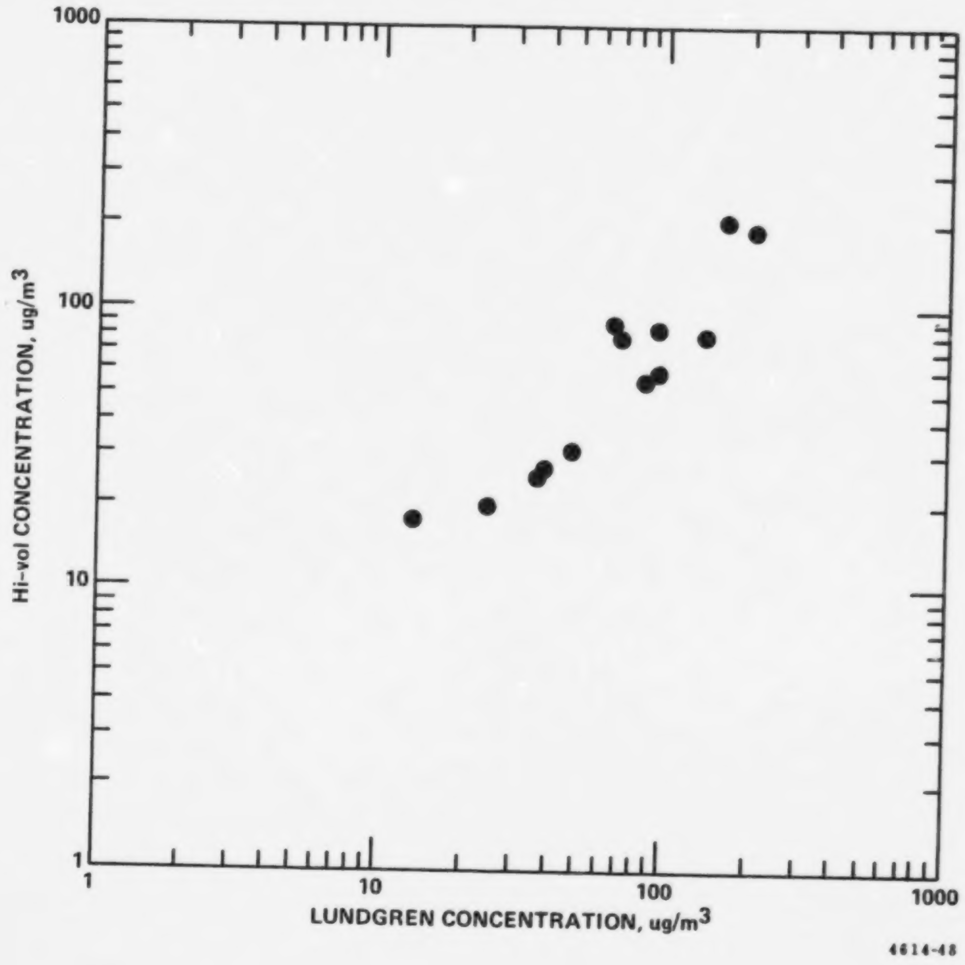

Figure 32. Comparison of particulate concentrations as determined from Lundgren impactors and high volume air samplers.

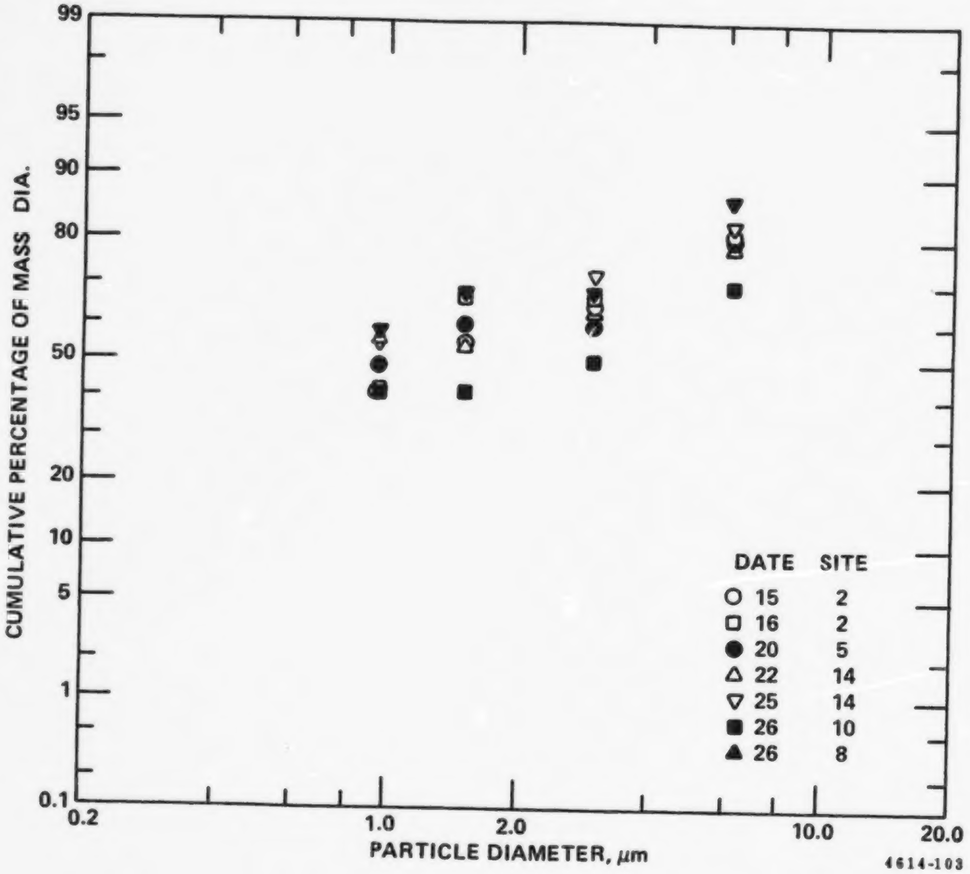

Figure 33. Ambient particle size distributions as measured with Sierra Model 234 cascade impactors.

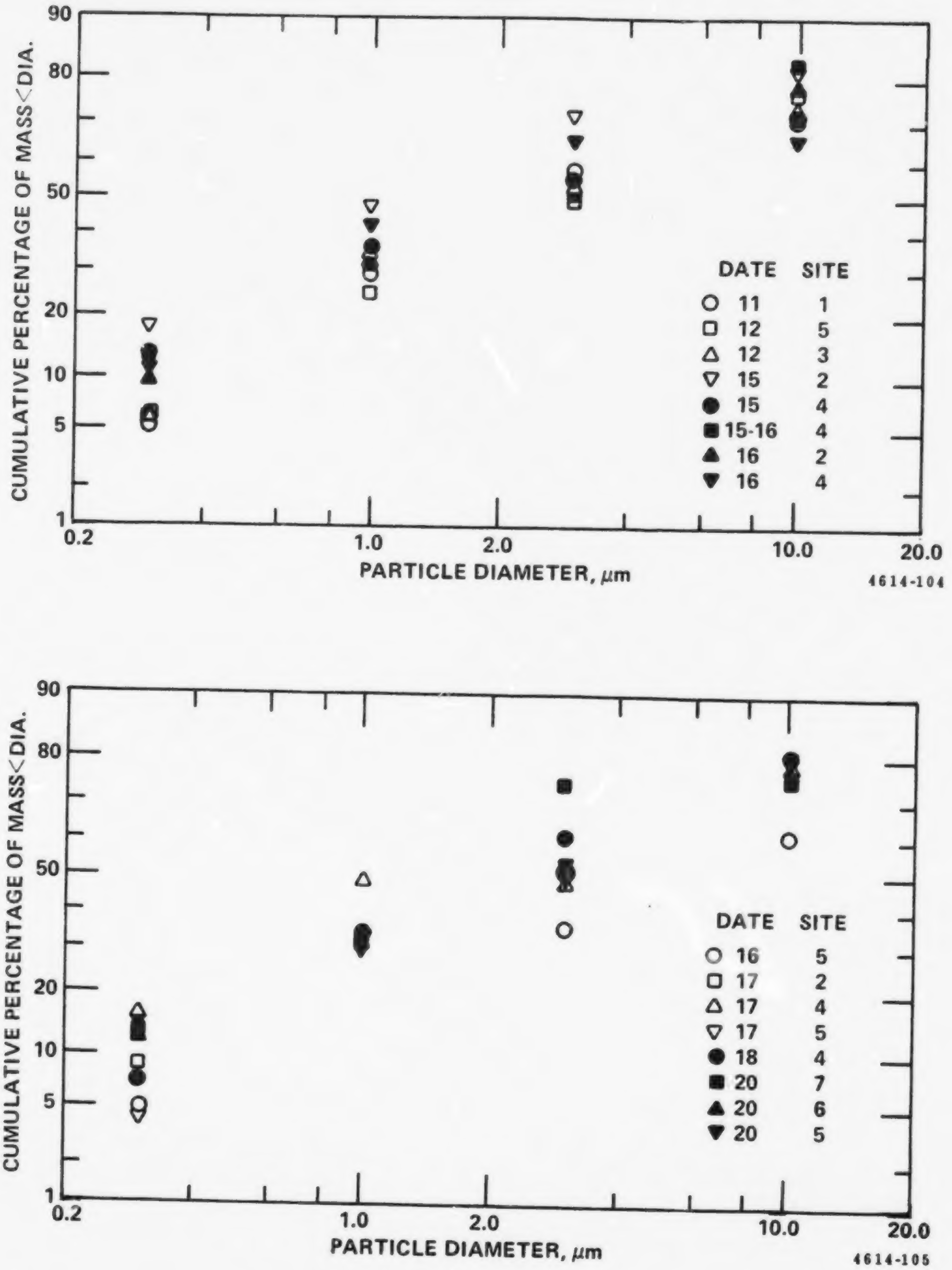

Figure 34. Ambient particle size distributions in the vicinity of the acid plant (measured gravimetrically with Lundgren cascade impactors).

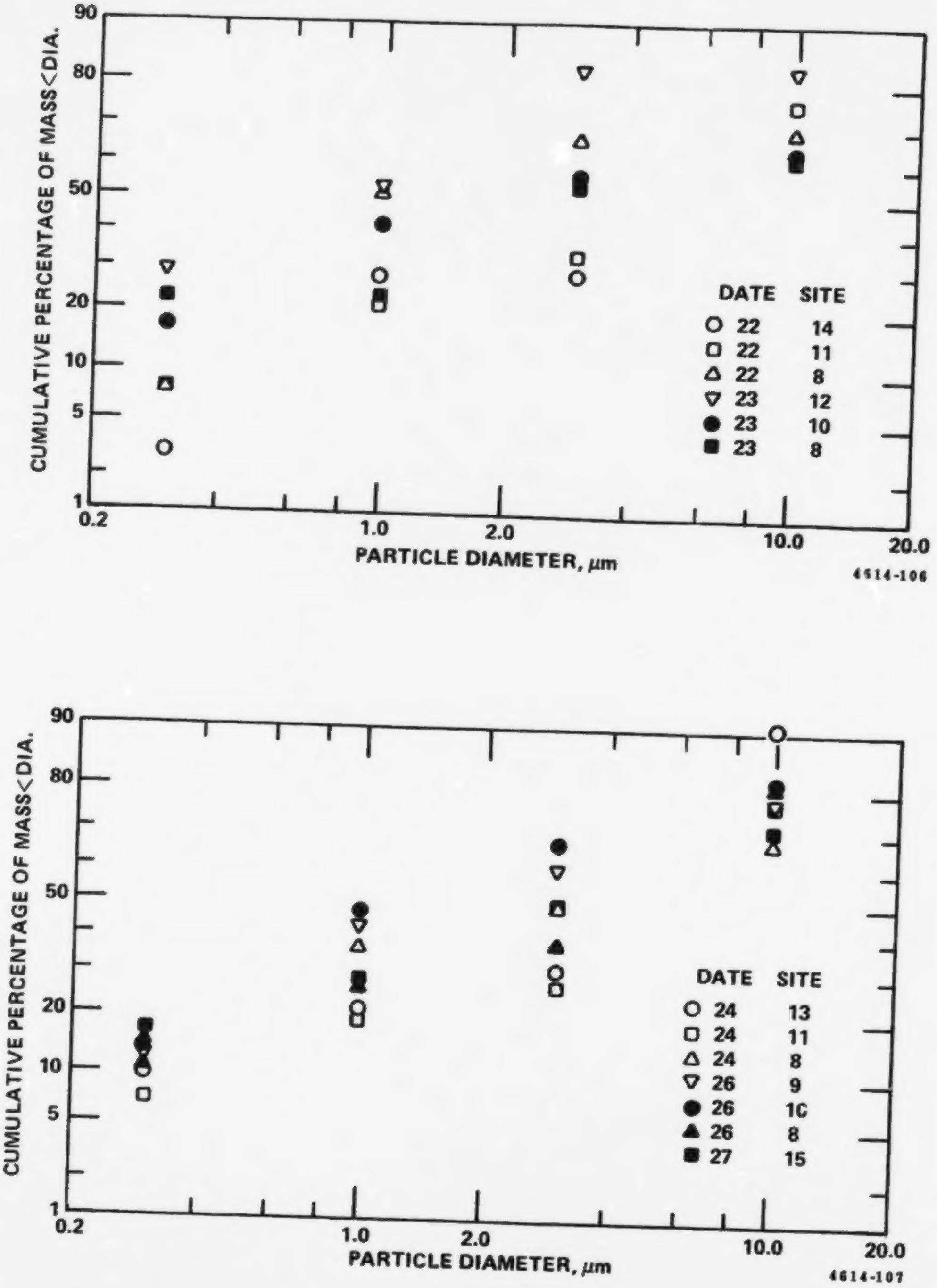

Figure 35. Ambient particle distributions in the vicinity of the pulp and paper plant (gravimetric measurements with Lundgren impactors).

Elemental composition of the ambient particulate matter

Sections of the teflon membrane hi-vol filters and the Lundgren impactor substrates and filters were analyzed by X-ray fluorescence and neutron activation techniques to provide information on the elemental composition of the ambient particulate matter. As originally planned, elemental analyses were only to be done on the Lundgren impactor samples; but following the Phase I testing it became apparent that the impactor data would probably be inadequate for quantifying the portions of the ambient particulate matter contributed by the target sources. This resulted from too few elements being present at concentrations above the detection limits with the relatively short sampling times available for the tests. So the decision was made to perform similar analyses on the teflon hi-vol filters. On the whole, the surface density of material on the hi-vol filters would be expected to be about five-fold greater than the particulate density on the surface of the Lundgren stages; thus the detectability of many elements would be considerably higher. Thirty-eight elements were detected on some or all of the teflon hi-vol filters by the combination of XRF and NAA techniques. Some of these were found on only a few of the filters and then only near the detection limits. However, thirty-six of the thirty-eight were detected at high enough concentrations to be useful in particulate source identification.

The concentrations of the detected elements and associated uncertainties are given in Appendix D3. The uncertainties quoted in the appendix include both measurement uncertainties provided by the analytical laboratories and estimates of the uncertainties in the gas volumes sampled by each filter. Other data associated with each filter sample can be found in Table 18 using the filter identification number as a key. Summing the concentrations of the elements detected on the filters (as oxides where appropriate) results in calculated mass concentrations that ranged from 33% to 65% of the gravimetrically determined mass concentrations. The larger discrepancies were associated with the samples having the lowest concentrations, implying that elements which were present but below detection limits were probably responsible for some of the discrepancy. Carbon, and other light elements and organics, not detectable by the techniques used, probably account for the remainder of the missing mass. A plot of the mass concentration derived from the elemental analyses versus those from the gravimetric concentration measurements is given in Figure 36.

Soil samples from some of the ambient sampling sites were also submitted for analysis. Only a limited particle size fraction of the bulk soil samples, after separation by means of a Bahco Micro-particle Classifier,[60] was analysed. This fraction contained particles in the 1.5 to 8 μm size range, corresponding to the range in which the impactor data indicated that most of the mineral elements in the ambient samples were found. The results

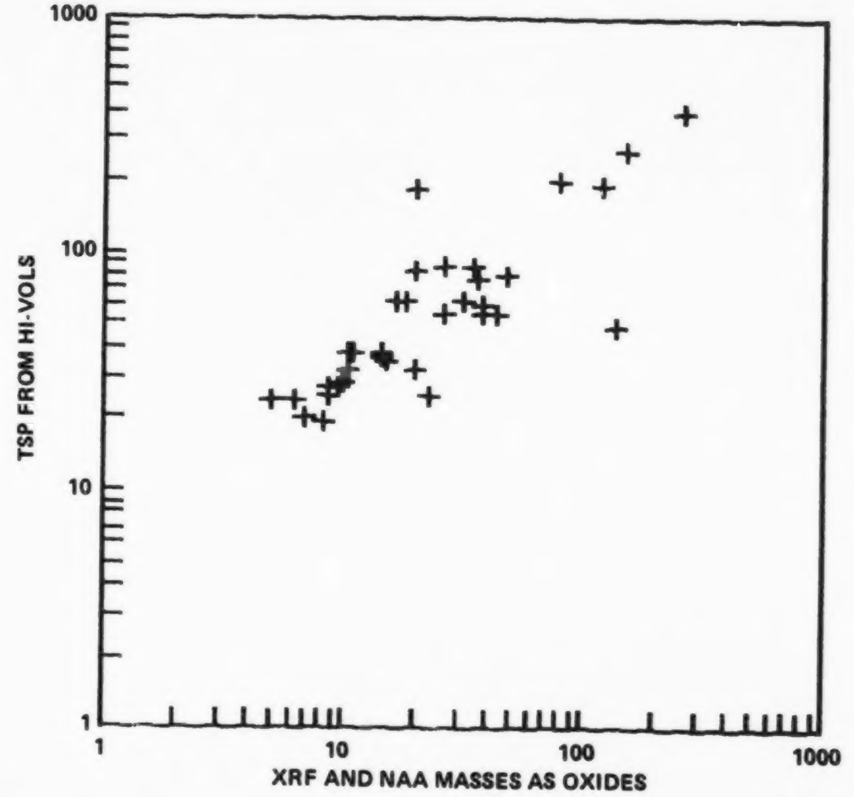

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Figure 36. Comparison of mass concentrations determined gravimetrically with those determined by summation of elemental concentrations (as oxides) from NAA and XRF analyses.

of these analyses are given in Table 20. Note that while the composition of the samples are fairly uniform for most elements, there are large differences among them for a few elements. These differences were later used in assessing the reasonableness of results of a reconstruction of the ambient filter data by factor analysis.

The substrates and filters from the Lundgren impactor runs were analyzed by XRF and NAA with the intent of obtaining elemental composition by size for comparison with the target source emission signatures previously discussed. However, the stage loadings were so light that, with the exception of sulfur and a half dozen other elements, the results were all essentially in the "noise" of the determinations. In addition to sulfur, valid data were obtained for the elements Al, Si, K, Ca, Ti, Fe, and Ba. In the case of the latter elements, the concentration of each in the size range collected by the backup filter were low and increased with increasing particle size. On the other hand, moderate to high concentrations of sulfur were found on the backup filters, and the concentrations dropped rapidly toward the larger particle sizes. Size distributions of the elements detected in the Lundgren impactor samples are shown in Figures 37 and 38, respectively for samples obtained in the vicinities of the acid plant and the pulp mill. The Lundgren data revealed mass median diameters for the sulfur (sulfate) distributions ranging from about 0.3 µm to 0.8 µm. The remaining elements detected had mass median diameters that were never smaller than 1 µm and which were frequently in excess of 10 µm (the upper resolution limit of the impactor) - values that were considerably larger than those found for sulfur. The tendencies of the distributions to flatten out between about 2 or 3 µm to 10 µm indicate that a third mode with a mass median diameter larger than 10 µm was present in many instances. These data thus show the ambient aerosol size distribution was typically tri-modal with a submicron mode typified by sulfur and perhaps containing other undetected "condensible" species, and other modes centered at about 1-5 µm and + 10 µm typified by more refractory mineral elements. This pattern in ambient aerosol size distributions has been found on numerous occasions in the past.[61]

TABLE 20. ELEMENTAL COMPOSITION OF SOIL SAMPLES

	Aug. 15		Aug. 24		Aug. 12	
	NAA	XRAY	NAA	XRAY	NAA	XRAY
AL	1.89E+04	1.47E+04	2.00E+04	1.95E+04	1.88E+04	2.00E+04
SI	3.02E+04	1.41E+05	3.54E+04	1.59E+05	4.03E+04	2.24E+05
P	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
S	N.A.	7.00E+02	N.A.	6.00E+02	N.A.	6.00E+02
CL	N.D.	2.00E+02	N.D.	N.A.	3.83E+02	3.00E+02
K	7.91E+03	4.10E+03	1.30E+04	4.23E+03	8.44E+03	4.39E+03
CA	2.90E+03	7.71E+03	5.93E+03	3.20E+03	2.32E+03	3.73E+03
TI	1.13E+03	4.10E+02	3.48E+03	1.87E+03	2.58E+03	7.70E+02
V	1.71E+01	1.00E+01	2.55E+01	3.00E+01	2.20E+01	1.00E+01
CR	2.80E+01	8.00E+02	2.97E+01	N.A.	9.46E+00	1.00E+04
MN	1.27E+02	3.20E+03	1.33E+02	4.00E+02	8.52E+01	6.60E+03
FE	3.00E+04	1.14E+05	1.04E+04	1.06E+04	6.10E+03	3.47E+04
CO	2.83E+00	N.A.	2.13E+00	N.A.	1.13E+00	3.30E+03
NI	9.24E+00	1.00E+02	N.A.	N.D.	N.A.	3.30E+03
CU	N.A.	N.D.	N.A.	N.D.	N.A.	3.10E+03
ZN	N.A.	N.D.	N.A.	1.00E+02	N.A.	3.00E+03
GA	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
GE	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
AS	2.59E+00	N.A.	3.18E+00	N.A.	N.D.	N.A.
SE	5.34E-01	N.A.	1.99E+00	N.A.	N.D.	N.A.
BR	2.32E+00	2.00E+02	2.04E+00	2.00E+02	3.97E+00	2.00E+02
RB	1.45E+01	N.D.	2.11E+01	N.D.	1.65E+01	N.D.
SR	N.A.	1.20E+02	N.A.	1.20E+02	N.A.	1.20E+02
ZR	N.A.	N.D.	N.A.	7.40E+02	N.A.	1.10E+02
PB	N.A.	7.00E+02	N.A.	4.00E+02	N.A.	5.00E+02
HG	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
W	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
CD	N.D.	N.A.	N.D.	2.00E+02	N.D.	N.A.
SN	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
SB	3.38E-01	N.A.	1.09E+00	N.A.	1.87E-01	N.A.
BA	1.92E+02	3.00E+02	3.40E+02	6.00E+02	1.72E+02	6.00E+02
I	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
MG	1.92E+03	N.A.	1.34E+03	N.A.	1.12E+03	N.A.
NA	2.44E+03	N.A.	2.48E+03	N.A.	3.69E+03	N.A.
SM	1.88E+00	N.A.	3.73E+00	N.A.	7.01E-01	N.A.
CE	2.34E+01	N.A.	7.49E+01	N.A.	1.15E+01	N.A.
U	6.37E-01	N.A.	1.24E+00	N.A.	2.25E-01	N.A.
TH	7.21E+00	N.A.	1.23E+01	N.A.	1.77E+00	N.A.
LA	N.D.	N.A.	4.16E+01	N.A.	6.12E+00	N.A.
AU	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
AG	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
SC	2.36E+00	N.A.	4.57E+00	N.A.	1.81E+00	N.A.
EU	6.84E-01	N.A.	3.27E+00	N.A.	6.03E-01	N.A.
CS	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
MO	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
LU	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.

* All units are micrograms/gram.

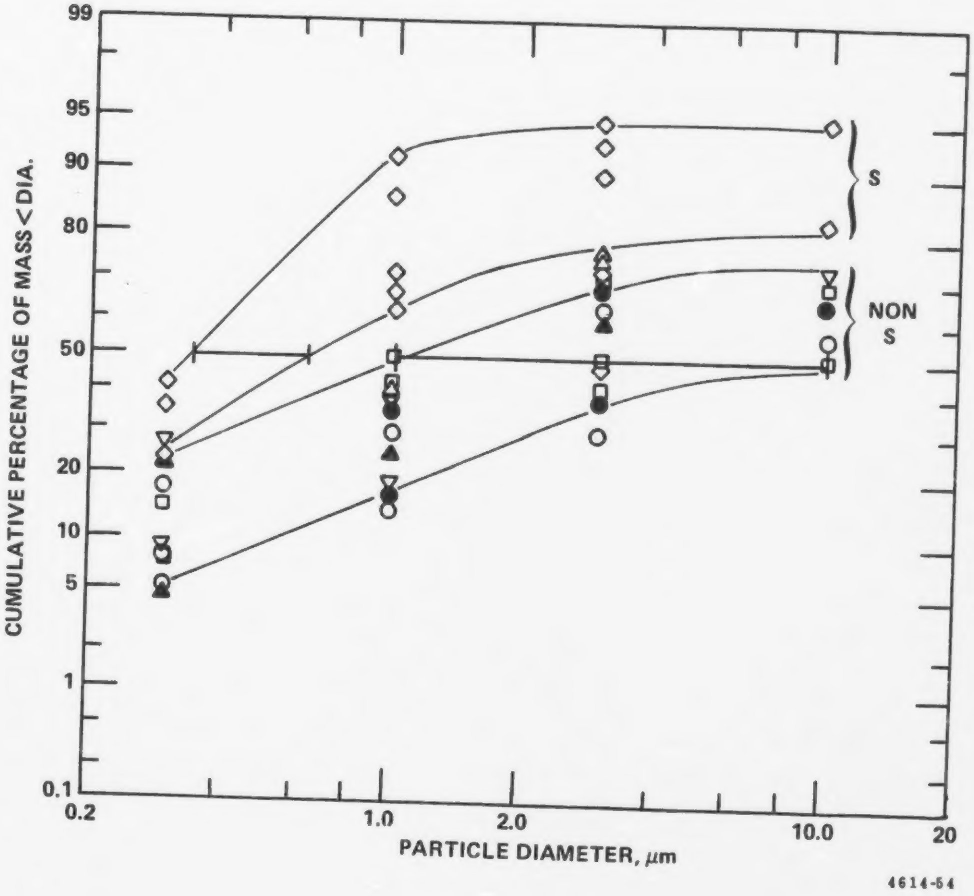

Figure 37. Distributions of sulfur (S) and other elements (NON-S) by particle size in the vicinity of the sulfuric acid plant.

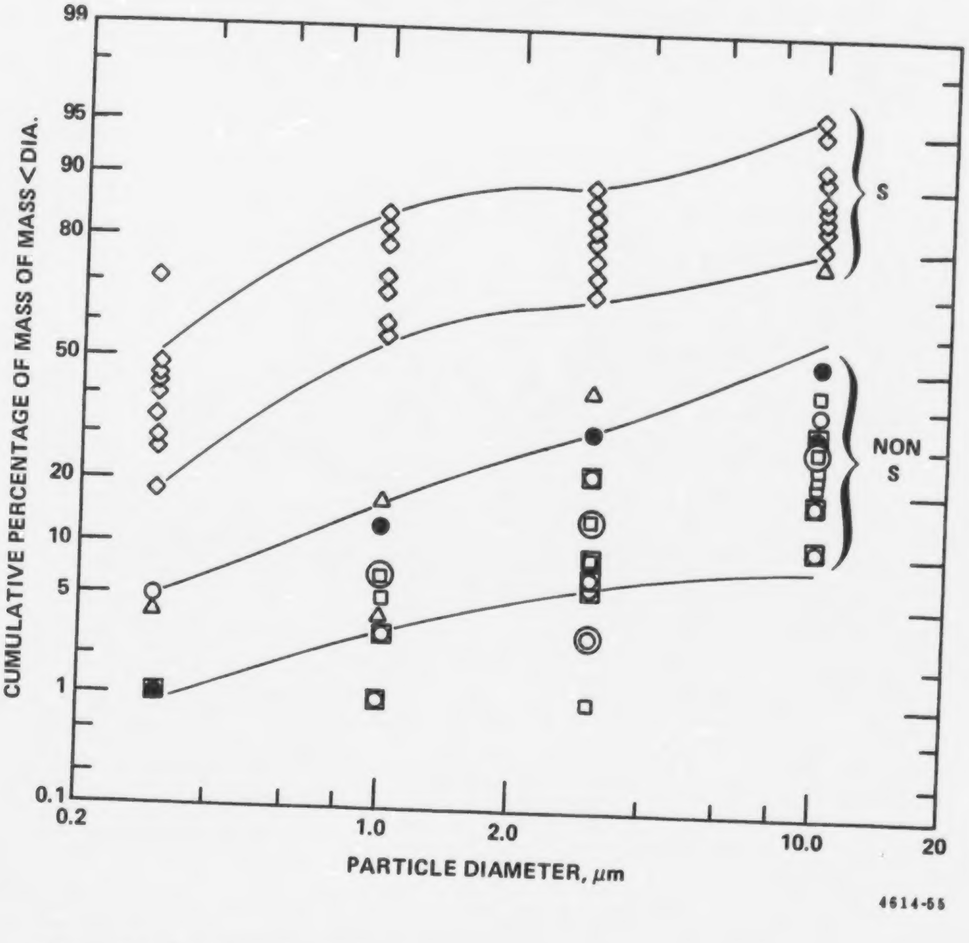

Figure 38. Distributions of sulfur (S) and other elements (NON-S) by particle size in the vicinity of the pulp and paper plant.

SECTION 8

SOURCE IMPACT ON TARGET AREA

Three approaches were taken to quantify the impact of the target sources on the study area. First, dispersion model predictions were made for downwind concentrations at the locations of the ambient sampling stations using averaging times comparable to the sampling periods used in the measurement program. The model was used to predict only sulfate, and NO_x concentrations. TSP concentrations can be predicted by scaling unit emission rates of these quantities to the predicted sulfate and NO_x results. Second, a form of principal component factor analysis[62-63] was applied to the correlation matrix of an ambient data base comprised of SO_2, NO_x, TSP, SO_4, NO_3, wind direction relative to the source and sampler locations, and 36 elements for which reasonably good concentration values were available from the Teflon membrane hi- vol filters. This analysis provided much insight into the probable number and nature of sources which had a detectable impact on the ambient stations, but did not quantify the impact on individual stations. Finally, Target Transformation Factor Analysis[64-67] was used in analyzing the data to isolate and quantify the impacts of specific sources having known signatures at each specific sampling location. The target transformation analysis used here involved a set of computer codes known collectively as "FANTASIA" (Factor Analysis To Apportion Sources In Aerosols). FANTASIA was developed by P. Hopke and his co-workers at the University of Illinois-Urbana, and a copy of the code was very kindly provided to Southern Research by Dr. Hopke.

High background concentrations of nitrates and sulfates made it difficult to test dispersion model predictions against the ambient data set in any meaningful fashion. The models did indicate that the target sources were, at most, minor contributors to the ambient concentrations. Thus factor analysis became the primary tool used in attempting to quantify the source contributions to the ambient loadings. Two forms of factor analysis were used in interpreting the data. First, principal component factor analysis was performed on the correlation matrix of the data to aid in determining the number and possible identities of significant sources and to screen the data for elements exhibiting "unique" behavior; that is, elements which showed little connection in concentration swings in common with others. The second, and more informative analysis, was performed using the technique known as Target Transformation Factor Analysis. The latter technique permits testing of specific source vectors (source "fingerprints") as possible contributors to the samples; and once a suitable set of source vectors has been selected, the method provides a reconstruction of the original data from the source signatures, quantifying the contributions of each source.

CORRELATION MATRIX ANALYSIS

A form of principal factor analysis was performed on the complete set of elemental analysis data augmented by the concentrations found for nitrates, nitric acid, sulfates, SO_2, NO, NO_x, TSP, and a variable related to the relative direction of the wind with respect to the plant and the sampling location. Various subsets of the full data base were analysed to permit the inclusion of NO_x and SO_2, for which there were many missing values. Elements which showed low values of communality in these analyses were excluded from the data set to be used in the TTFA approach. Exceptions to this exclusion were made for sulfates (or sulfur) and nitrates, which had communalities of about 0.5. The latter were retained because they were the principal subjects of the study. Table 21 gives the results of a rotated, six factor solution of the correlation matrix using twenty-six of the elements that were finally selected for use in the TTFA analysis.

The first factor shows heavy factor loadings for elements common to soil, and fairly clearly represents windblown soil. The second factor shows high loadings on Ar, Se, and Ce. When zinc is included in the data set it also shows a relatively high loading on this factor. This factor was traced to samples from a single location - Site 11 - and appeared to result from emissions from a galvanizing plant which was upwind of that location when the wind was out of the ENE. The third factor has significant loadings on only sulfates and nitrates and probably represents a secondary aerosol (the size distribution of sulfur from Lundgren impactor data would support this conjecture). Note that most of the explained variance for these two variables arises from this factor. The fourth factor is associated with the TiO_2/acid plant complex but does not arise directly from the sources tested. The area around the TiO_2/acid plant complex was liberally coated with TiO_2 dust and this factor may represent resuspension of some of this material together with fugitive emissions from the complex. The standard error in the factor loadings given in Table 21 is 0.15 thus the fifth and sixth factors are not significant. The four factors for which the loadings are significant are sufficient to explain 83% of the variance in the input data matrix.

TARGET TRANSFORMATION FACTOR ANALYSIS

Target transformation factor analysis uses a linear combination of known source profiles (signatures) to reconstruct an observed data set. The particular computer code used in this work was developed by P. Hopke and co-workers at the University of

TABLE 21. RESULTS OF PRINCIPAL FACTOR ANALYSIS

	FACTOR LOADING						CONTRIBUTION TO VARIANCE						EXPLAINED VARIANCE
FACT.	1	2	3	4	5	6	1	2	3	4	5	6	
VARIABLE													
CO	.99						.98						.98
EU	.98			-.19			.96			.04			1.00
AL	.98			.16			.95			.02			.98
SI	.98			.18			.95			.03			.99
K	.97			.25			.93			.06			.99
SM	.96		.17	.13		.16	.93		.03	.02		.03	1.00
U	.95			.12		.17	.91			.01		.03	.95
MN	.95	.19		.16	-.15		.90	.04		.02	.02		.93
FE	.94	.12		.24		.15	.89	.02		.06		.02	.98
LA	.95		.27	.17			.89		.07	.03			.99
SB	.94	.22		-.19	-.19	.12	.87	.05		.03	.04	.02	1.01
CA	.93			.29			.86			.08			.94
TH	.89		.30	.32			.80		.09	.10			.99
SC	.86	.37		.22		.18	.74	.14		.05		.03	.96
CR	.85	.17	.28	.17			.72	.03	.08	.03			.86
CS	.85		-.35		.20	.15	.72		.12		.04	.02	.91
MG	.82	.52		.17			.66	.27		.03			.97
TSP	.82	.25	.37		.23		.66	.06	.13		.05		.91
CE	.20	.86		-.12		.21	.04	.73		.01		.04	.83
AS		.81	.27					.66	.07				.73
SE	.20	.74	-.17			-.19	.04	.54	.03			.04	.64
NO3-		.22	.73			-.23		.05	.53			.05	.63
S	.19		.60		.15	.29	.04		.36		.02	.08	.50
TI				.92						.85			.85
P	.43			.88			.18			.77			.96
CL				.78	.19	-.18				.61	.04	.03	.68
BA		.36	-.15	.53	-.25	.24		.13	.02	.28	.06	.06	.56
PB	.27			.32	.53		.07			.10	.28		.45
Source:	SOIL	GAL. PLANT	SEC. AERO	CYAN AREA SOIL	AUTO?	?							Total Explained Variance:
Contribution to total variance:							15.7	2.72	1.53	3.25	.54	.46	24.2

Fraction of total variance explained: .86

Illinois-Urbana and has been extensively described in the literature under the acronym "FANTASIA". FANTASIA may be used to test elements of a data set for unique behavior; to generate possible source vectors or signatures; to test known potential source vectors as real contributors to observed data; to predict missing values in either the observed data or in source vectors; and finally, to quantify the contributions of individual sources to individual samples within a data set. All of these features were utilized in some fashion in analyzing the data from this test.

The FANTASIA input data matrix consisted, in different reconstruction attempts, of various combinations of the concentrations of twenty to forty-seven elements, gases, and radicals associated with each of thirty-nine ambient filter samples. The data on the elemental concentrations were augmented with values for TSP from the companion hi-vol impactor runs; sulfate, nitrate, and nitric acid concentrations determined from the same teflon filter hi-vol runs which provided the data on the elements; and average concentrations of SO_2 at each sampling location for the time spans covered by the hi-vol samples. There were too many missing values in the NO_x data for its inclusion to be meaningful.

Source vectors used in attempting to regenerate the data were the measured emission strengths of the variables in the ambient data matrix for the various units in the plants, the compositions of the soil samples discussed earlier, [illegible] various potential source vectors obtained from the literature and the Phase I test for automotive sources, power plants, sea-salt, etc. The predictive capabilities of FANTASIA were used to refine the vectors obtained from the literature for this specific application. Estimates were obtained in the same fashion for effective source strengths for the plants for (1) elements such as arsenic, selenium, and chlorine which, because of their volatility, would have been under-represented in the actual source particulate samples; and (2) for sulfates and nitrates which would, or could, change from the measured source strengths by reactions after discharge from the stacks. Because of the linear nature of the model, any estimates obtained in this fashion could represent only averages and would not provide time/distance dependences for reactive components.

Table 22 summarizes the final source vectors used in attempting to regenerate the data. No satisfactory regeneration could be obtained using any combination of these source vectors as long as sulfur (or sulfates) and nitrates were included in the data set. Uniqueness tests for these variables confirmed the conclusions reached concerning them from the principal components analysis - they do indeed exhibit unique behavior and cannot be directly linked to any source which might be potentially identifiable by its signature in the remaining elements.

TABLE 22. SOURCE VECTORS USED IN TTFA RECONSTRUCTION ATTEMPTS

		Acid Plant	Calciner	Recovery	Smelt T	Power B	Lime Kil	1508DDW	2408DKP	1208DUW
AL	1	-0.3298E+02	-0.1031E+03	0.0000E+00	0.1218E+02	0.2192E+04	0.4067E+02	0.1885E+03	0.2002E+03	0.1883E+03
SI	2	-0.7309E+03	-0.3290E+04	0.1225E+04	0.5479E+03	0.0000E+00	0.4814E+03	0.1410E+04	0.1590E+04	0.2240E+04
P	3	0.0000E+00	0.0000E+00	0.3808E+03	0.1257E+03	0.9378E+03	0.1982E+03	0.0000E+00	0.0000E+00	0.0000E+00
S	4	0.0000E+00	0.0000E+00	0.2252E+05	0.5595E+04	0.2721E+04	0.1191E+05	0.7000E+01	0.6000E+01	0.6000E+01
CH	5	-0.3125E+01	-0.1427E+02	0.3784E+04	0.1475E+04	0.9607E+03	0.4597E+03	0.0000E+00	0.0000E+00	0.3828E+01
K	6	0.0000E+00	0.1298E+02	0.4056E+04	0.2784E+04	0.4627E+04	0.1394E+04	0.4100E+02	0.4230E+02	0.4390E+02
CA	7	-0.3753E+02	-0.5962E+02	0.0000E+00	0.0000E+00	0.1017E+05	0.2076E+03	0.7710E+02	0.3200E+02	0.3730E+02
TI	8	0.5950E+00	0.1089E+01	0.0000E+00	0.0000E+00	0.5462E+02	0.0000E+00	0.4100E+01	0.1870E+02	0.7700E+01
V	9	0.4760E-02	0.1995E-01	0.0000E+00	0.1855E+01	0.2185E+01	0.3774E+01	0.1714E+00	0.2546E+00	0.2196E+00
CR	10	0.1146E+00	0.4494E+01	0.2416E+01	0.4894E+00	0.4843E+01	0.1852E+02	0.2804E+00	0.2967E+00	0.9460E-01
MN	11	-0.4522E-01	0.4389E-01	0.3196E+01	0.7270E+01	0.3702E+03	0.8826E+01	0.1266E+01	0.1331E+01	0.8523E+00
FE	12	0.2090E+01	0.6177E+01	0.4967E+02	0.1796E+02	0.6596E+03	0.5191E+02	0.1140E+04	0.1060E+03	0.3470E+03
CO	13	0.9044E-02	0.4110E-01	0.6374E-01	0.1677E+00	0.1245E+01	0.7506E+00	0.2830E-01	0.2130E-01	0.1130E-01
NI	14	0.4897E+00	0.9933E+01	0.0000E+00	0.7527E+01	0.2264E+01	0.7275E+00	0.9240E-01	0.0000E+00	0.0000E+00
CU	15	-0.6045E+00	-0.2925E+01	0.3311E+02	0.1796E+02	0.3092E+02	0.2360E+02	0.0000E+00	0.0000E+00	0.3100E+02
ZN	16	0.4316E+00	0.1611E+01	0.1260E+02	0.1206E+01	0.1426E+03	0.1244E+03	0.0000E+00	0.0000E+00	0.0000E+00
AS	19	0.9163E-02	0.1731E+01	0.0000E+00	0.0000E+00	0.5421E+00	0.0000E+00	0.2590E-01	0.3180E-01	0.0000E+00
SE	20	0.1122E+00	0.7190E+00	0.7409E-01	0.0000E+00	0.7240E+00	0.3723E+00	0.5340E-02	0.1990E-01	0.0000E+00
BR	21	-0.2023E-01	-0.1153E+00	0.1767E+02	0.5004E+01	0.5629E+01	0.4855E+01	0.2320E-01	0.2040E-01	0.3970E-01
RB	22	-0.1761E+00	0.4828E-01	0.3311E+02	0.8981E+01	0.0000E+00	0.9439E+01	0.0000E+00	0.0000E+00	0.0000E+00
SR	23	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1200E+01	0.1200E+01	0.1200E+01
ZR	24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.7400E+01	0.1100E+01
PB	25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1134E+03	0.1746E+03	0.7000E+01	0.4000E+01	0.5000E+01
HG	26	0.9496E-01	0.1454E+01	0.0000E+00	0.0000E+00	0.9481E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
W	27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
CD	28	-0.1942E+00	-0.4608E+00	0.0000E+00	0.0000E+00	0.2256E+01	0.1260E+02	0.0000E+00	0.0000E+00	0.0000E+00
SN	29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SB	30	0.2117E+00	0.1053E+01	0.2939E-01	0.1344E+00	0.2311E+01	0.1343E+00	0.3380E-02	0.1090E-01	0.1870E-02
BA	31	0.1484E+01	0.6348E+01	0.6622E+02	0.1302E+03	0.2473E+03	0.2360E+02	0.3000E+01	0.6000E+01	0.6000E+01
I	32	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
MG	33	-0.2718E+01	-0.1236E+02	0.0000E+00	0.0000E+00	0.8816E+03	0.2938E+02	0.1917E+02	0.1343E+02	0.1120E+02
NA	34	-0.5417E+02	-0.2067E+03	0.4186E+05	0.4153E+05	0.8957E+03	0.2220E+05	0.2438E+02	0.2485E+02	0.3690E+02
SM	35	-0.4760E-03	-0.7980E-03	0.0000E+00	0.4715E-02	0.6691E-01	0.0000E+00	0.1880E-01	0.3730E-01	0.7010E-02
CE	36	0.2978E+01	0.1859E+00	0.0000E+00	0.0000E+00	0.1230E+01	0.7150E-01	0.2340E+00	0.7489E+00	0.1154E+00
U	37	-0.1012E-01	-0.3990E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.4106E-01	0.6370E-02	0.1240E-01	0.2250E-02
TH	38	0.1666E-02	-0.9177E-02	0.0000E+00	0.1684E-02	0.1010E+00	0.0000E+00	0.7210E-01	0.1234E+00	0.1770E-01
LA	39	-0.3296E-01	-0.1061E+00	0.0000E+00	0.0000E+00	0.7284E+00	0.0000E+00	0.0000E+00	0.4161E+00	0.6120E-01
AU	40	0.0000E+00	0.1995E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
AG	41	0.2261E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SC	42	0.5950E-03	0.7980E-03	0.1159E-01	0.3368E-03	0.8680E-01	0.8731E-02	0.2360E-01	0.4570E-01	0.1810E-01
EU	43	0.3689E-02	0.6783E-02	0.0000E+00	0.0000E+00	0.1255E-01	0.0000E+00	0.6840E-02	0.3270E-01	0.6030E-02
CS	44	0.3820E-01	0.1373E+00	0.1419E+01	0.5254E+00	0.1448E+01	0.4691E+00	0.0000E+00	0.0000E+00	0.0000E+00
MO	45	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
LU	46	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SO4	53	0.2975E+03	0.4795E+05	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

(continued)

TABLE 22 (continued)

		Coal 1	Sea Salt	Coal 2	NBS 55	AVE DIRT	Ave.AmCy	Ave.U.C.	U.C.Cool
AL	1	0.3773E+01	0.0000E+00	0.1200E+03	0.1270E+00	0.1923E+03	-0.1361E+03	0.5613E+03	0.2643E+02
SI	2	0.4142E+01	0.0000E+00	0.0000E+00	0.2100E+00	0.1747E+04	-0.4021E+04	0.5636E+03	0.5146E+03
P	3	0.7555E-01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4106E+03	0.1620E+03
S	4	0.1228E+02	0.0000E+00	0.3882E+04	0.0000E+00	0.6333E+01	0.0000E+00	0.1068E+05	0.8751E+04
CH	5	0.9128E+01	0.1723E+01	0.0000E+00	0.4200E-04	0.1276E+01	-0.1740E+02	0.1670E+04	0.9674E+03
K	6	0.5039E+00	0.0000E+00	0.1040E+02	0.1610E-01	0.4240E+02	0.1298E+02	0.3215E+04	0.2089E+04
CA	7	0.1644E+00	0.0000E+00	0.4370E+02	0.4700E-01	0.4880E+02	-0.9715E+02	0.2595E+04	0.1038E+03
TI	8	0.1429E+00	0.0000E+00	0.0000E+00	0.7400E-02	0.1017E+02	0.1684E+01	0.1366E+02	0.0000E+00
V	9	0.1941E-01	0.0000E+00	0.5200E+00	0.2400E-03	0.2152E+00	0.2471E-01	0.1954E+01	0.2815E+01
CR	10	0.0000E+00	0.0000E+00	0.3500E+00	0.1300E-03	0.2239E+00	0.4609E+01	0.6568E+01	0.9506E+01
MN	11	0.8278E-02	0.9000E-03	0.4100E+00	0.5000E-03	0.1150E+01	-0.1330E-02	0.9736E+02	0.8048E+01
FE	12	0.5663E+01	0.3000E-04	0.8500E+02	0.6200E-01	0.5310E+03	0.8266E+01	0.1948E+03	0.3494E+02
CO	13	0.2864E-02	0.0000E+00	0.5500E-01	0.0000E+00	0.2030E-01	0.5014E-01	0.5569E+00	0.4592E+00
NI	14	0.0000E+00	0.0000E+00	0.2150E+00	0.1600E-03	0.3080E-01	0.1042E+02	0.2630E+01	0.4127E+01
CU	15	0.1717E-01	0.0000E+00	0.3900E+00	0.0000E+00	0.1033E+02	-0.3529E+01	0.2640E+02	0.2078E+02
ZN	16	0.3100E-01	0.5000E-04	0.5100E+00	0.2000E-03	0.0000E+00	0.2042E+01	0.7019E+02	0.6278E+02
AS	19	0.1820E+00	0.0000E+00	0.2800E+00	0.5800E-04	0.1923E-01	0.1740E+01	0.1355E+00	0.0000E+00
SE	20	0.2900E-01	0.0000E+00	0.3300E+00	0.1000E-04	0.8413E-02	0.8312E+00	0.2926E+00	0.1862E+00
BR	21	0.1510E+00	0.6800E-02	0.0000E+00	0.1200E-04	0.2777E-01	-0.1355E+00	0.8289E+01	0.4930E+01
RB	22	0.0000E+00	0.0000E+00	0.0000E+00	0.1300E-03	0.0000E+00	-0.1278E+00	0.1288E+02	0.9210E+01
SR	23	0.0000E+00	0.0000E+00	0.0000E+00	0.1700E-02	0.1200E+01	0.0000E+00	0.0000E+00	0.0000E+00
ZR	24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2833E+01	0.0000E+00	0.0000E+00	0.0000E+00
PB	25	0.1002E-01	0.0000E+00	0.3800E+00	0.7500E-04	0.5333E+01	0.0000E+00	0.7199E+02	0.8731E+02
HG	26	0.1080E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1549E+01	0.2370E-01	0.0000E+00
W	27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
CD	28	0.2715E-02	0.0000E+00	0.1900E-01	0.0000E+00	0.0000E+00	-0.6551E+00	0.3713E+01	0.6298E+01
SN	29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SB	30	0.3574E-02	0.0000E+00	0.0000E+00	0.7000E-05	0.5383E-02	0.1265E+01	0.6522E+00	0.1343E+00
BA	31	0.7977E-01	0.0000E+00	0.2800E+01	0.2700E-02	0.5000E+01	0.7832E+01	0.1168E+03	0.7691E+02
I	32	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
MG	33	0.3457E+00	0.0000E+00	0.8200E+01	0.0000E+00	0.1460E+02	-0.1507E+02	0.2277E+03	0.1469E+02
NA	34	0.1121E+02	0.1117E+01	0.9500E+01	0.3200E-02	0.2871E+02	-0.2609E+03	0.2662E+05	0.3186E+05
SM	35	0.4460E-03	0.1000E-05	0.0000E+00	0.0000E+00	0.2104E-01	-0.1274E-02	0.1791E-01	0.2358E-02
CE	36	0.2553E-02	0.1000E-03	0.0000E+00	0.0000E+00	0.3661E+00	0.3164E+01	0.3254E+00	0.3575E-01
U	37	0.5580E-03	0.0000E+00	0.0000E+00	0.0000E+00	0.7007E-02	-0.5002E-01	0.1026E-01	0.2053E-01
TH	38	0.6720E-03	0.0000E+00	0.0000E+00	0.0000E+00	0.7107E-01	-0.7511E-02	0.2567E-01	0.8420E-03
LA	39	0.3334E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.1591E+00	-0.1391E+00	0.1821E+00	0.0000E+00
AU	40	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1995E-02	0.0000E+00	0.0000E+00
AG	41	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2261E-02	0.0000E+00	0.0000E+00
SC	42	0.2146E-02	0.0000E+00	0.0000E+00	0.0000E+00	0.2913E-01	0.1393E-02	0.2686E-01	0.4534E-02
EU	43	0.1050E-03	0.3000E-05	0.0000E+00	0.0000E+00	0.1519E-01	0.1047E-01	0.3137E-02	0.0000E+00
CS	44	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1755E+00	0.9653E+00	0.4972E+00
MO	45	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
LU	46	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
SO4	53	0.3330E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4825E+05	0.0000E+00	0.0000E+00

TABLE 22. KEY TO SOURCE IDENTIFICATIONS

Acid Plant - cyanamid sulfuric acid plant

Calciner - Cyanamid calciners

Recovery - Union Camp recovery boilers

Smelt T - Union Camp smelt tank vents

Power B - Union Camp bark fired boilers

Lime Kil - Union Camp lime kilns

1508 DDW - Soil sample from Site 4

2408 DKP - Soil sample from Site 11

1208 DUW - Soil sample from Site 5

Coal 1 - High sulfur coal-fired boiler source vector from Phase 1 test

Sea Salt - Literature source vector for sea salt

Coal 2 - Literature source vector for coal fired boilers

NBS 55 - NBS SRM soil sample

Ave Dirt - Average soil composition from Savannah area samples

Ave. AmCy - Flow weighted average emission signature for Cyanamid acid plant and calciners

Ave. U.C. - Flow weighted average emission signature for Union Camp sources without scrubbers

U.C. Cool - Flow weighted average emission signature for Union Camp sources with scrubbers

Potential source vectors were also obtained by using the predictive capabilities of FANTASIA to independently generate a set of possible vectors. Six possible source vectors generated in this fashion are given in Table 23. One of these very closely matches a composite of the soil samples, another shows high concentrations of Ti and P, and a third is very high in sulfur and nitrates and has a high association with the element vanadium. The Ti-P vector is, as previously mentioned, associated with the area in which the acid plant is located, but is not directly related to the sources sampled there, nor does it have much sulfur associated with it. The sulfate-nitrate vector has no resemblance to either the acid plant sources or the pulp-mill and cannot be accounted for by any known local sources, leaving either secondary aerosol formation and/or long range transport to account for its origin. The linkage with vanadium makes long range transport likely as that element is typically associated with oil combustion and fuel oil was not in use in the Savannah area in any significant way during these tests.

COMPARISON WITH DISPERSION MODELS

Source emission data and meterological data for each test day were used with a dispersion model to predict average concentrations for each test day at all downwind sampling sites. The model was based on information contained in Turner's "Workbook of Atmospheric Dispersion Estimates"[68] and the Texas Air Control Board's "Dispersion Equation Solutions by Calculator: A Guide for Air Pollution Engineers and Scientists"[69]). Model predictions were made only for the plants' contributions to SO_4 and in the case of the pulp-mill, NO_x; however, values for other parameters can be obtained by scaling the SO_4 and NO_x values for the relative source strength of the parameter of interest. Individual calculations were made for each of the emission sources at each plant site and then summed to obtain the net contributions. The model was used in this fashion to predict downwind concentrations based on two different plume rise algorithms, the Brigg's plume rise algorithm and the older Holland equations. Observations of plume behavior at the plants in question lead the authors to believe that the Holland equations are more realistic in the current application. The plume rise predicted by the Brigg's equations seemed to be too large in all cases. Further, in a long term dispersion model validation project carried out by a group of investigators for the EPRI,[70] it was found that the Brigg's equation systematically overpredicted the plume rise by about a factor of two. The effect of the over-prediction of plume rise is an under-estimation of near-source impact. Therefore only the results based on the Holland equations are reported here.

The results of the model runs for sulfate are shown in Figures 39 and 40. The model predictions shown are based on one-hour averaging times - concentrations for longer averaging

TABLE 23. TTFA PREDICTED SOURCE VECTORS

	RELATIVE CONCENTRATION					
VECTOR:	1	2	3	4	5	6
ELEMENT						
AL	2.4E-1	1.9E-1	2.4E-1	3.1E-1	3.2E-1	2.7E-1
SI	1	1	1	1	1	1
P	4.8E-3	4.8E-2	9.4E-3	9.3E-3	1.5E-2	7.4E-3
S	5.4E-2	4.1E00	3.6E-1	8.0E-1	2.7E-1	5.0E-1
CL	1.8E-2	1.1E-1	3.0E-2	7.3E-2	1.4E-1	3.0E-2
K	6.2E-2	1.8E-1	7.3E-2	1.0E-1	7.9E-2	8.0E-2
CA	1.1E-1	2.7E-1	1.2E-1	1.9E-1	1.3E-1	1.5E-1
TI	6.4E-2	6.0E-1	1.2E-1	4.8E-3	6.4E-9	8.4E-2
V	1.7E-4	7.9E-3	9.9E-4	1.9E-3	1.2E-3	8.9E-4
CR	4.4E-4	1.5E-3	5.4E-4	5.6E-4	1.0E-3	7.1E-4
MN	1.4E-3	3.8E-3	1.6E-3	2.3E-3	2.3E-3	2.0E-3
FE	2.0E-1	3.2E-1	2.1E-1	2.6E-1	2.4E-1	2.3E-1
CO	4.6E-5	1.0E-4	5.3E-5	5.8E-5	7.4E-5	7.1E-5
NI	4.6E-8	2.7E-7	1.8E-7	3.5E-4	1.2E-3	3.1E-3
ZN	4.7E-3	2.1E-2	6.1E-3	9.3E-3	1.3E-2	6.4E-3
AS	2.4E-5	3.7E-4	4.6E-5	2.1E-4	8.9E-5	3.4E-5
SE	1.3E-4	1.0E-3	1.8E-4	2.6E-4	2.2E-4	3.6E-4
BR	2.0E-4	1.7E-3	4.8E-4	3.2E-3	2.3E-3	5.0E-4
SR	2.3E-2	1.3E-1	1.6E-2	5.6E-2	4.5E-7	8.4E-2
PB	1.3E-2	1.9E-1	1.7E-2	1.1E-2	2.1E-1	8.8E-2
HG	2.4E-4	5.6E-6	2.6E-4	1.4E-4	1.4E-3	3.8E-4
CD	9.E-10	2.4E-3	6.E-10	3.8E-3	8.3E-3	9.7E-8
SB	4.6E-4	1.4E-3	5.7E-4	2.7E-4	7.3E-4	7.1E-4
BA	5.9E-3	7.0E-3	1.7E-3	3.9E-2	2.1E-2	1.7E-2
MG	2.2E-2	5.0E-2	2.4E-2	4.5E-2	3.5E-2	3.3E-2
SM	2.8E-5	6.3E-6	2.8E-5	4.1E-5	4.3E-5	3.4E-5
CE	1.7E-2	6.9E-9	1.6E-2	4.6E-2	2.9E-2	1.6E-2
U	3.1E-5	3.7E-5	3.1E-5	2.3E-5	2.4E-5	3.1E-5
TH	5.5E-5	2.5E-5	5.3E-5	7.4E-5	7.1E-5	6.5E-5
LA	1.6E-4	1.1E-4	1.6E-4	2.5E-4	2.5E-4	1.8E-4
AU	1.7E-5	2.8E-5	1.5E-5	6.8E-6	4.5E-5	2.4E-5
SC	4.5E-5	1.2E-4	5.1E-5	6.6E-5	4.7E-5	5.3E-5
EU	6.2E-6	4.4E-6	6.5E-6	5.9E-6	5.8E-6	5.2E-6
CS	1.8E-5	2.7E-5	2.2E-5	8.5E-9	4.2E-5	3.4E-5
HNO3	3.7E-3	2.2E00	1.4E-1	4.7E-1	1.9E-1	2.4E-1
NO3-	2.3E-2	1.9E-1	4.7E-2	1.3E-1	1.2E-1	5.1E-2
POSSIBLE ORIGIN:	SOIL	SECONDARY AEROSOL	CYAN. AREA SOIL	GALV. PLANT	UNKNOWN	UNKNOWN

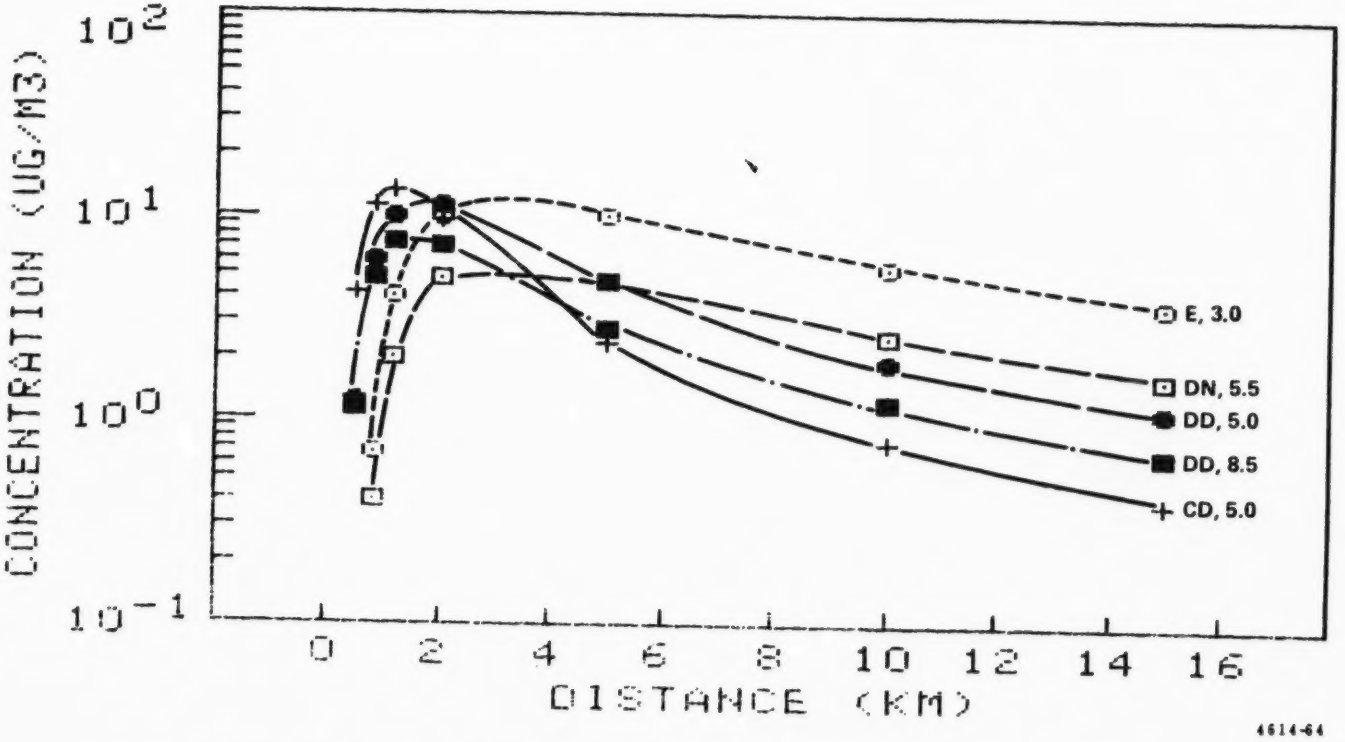

Figure 39. Cyanamid 1 hour average sulfate concentration vs. distance downwind. Letter and number combinations refer to stability classes and wind speeds.

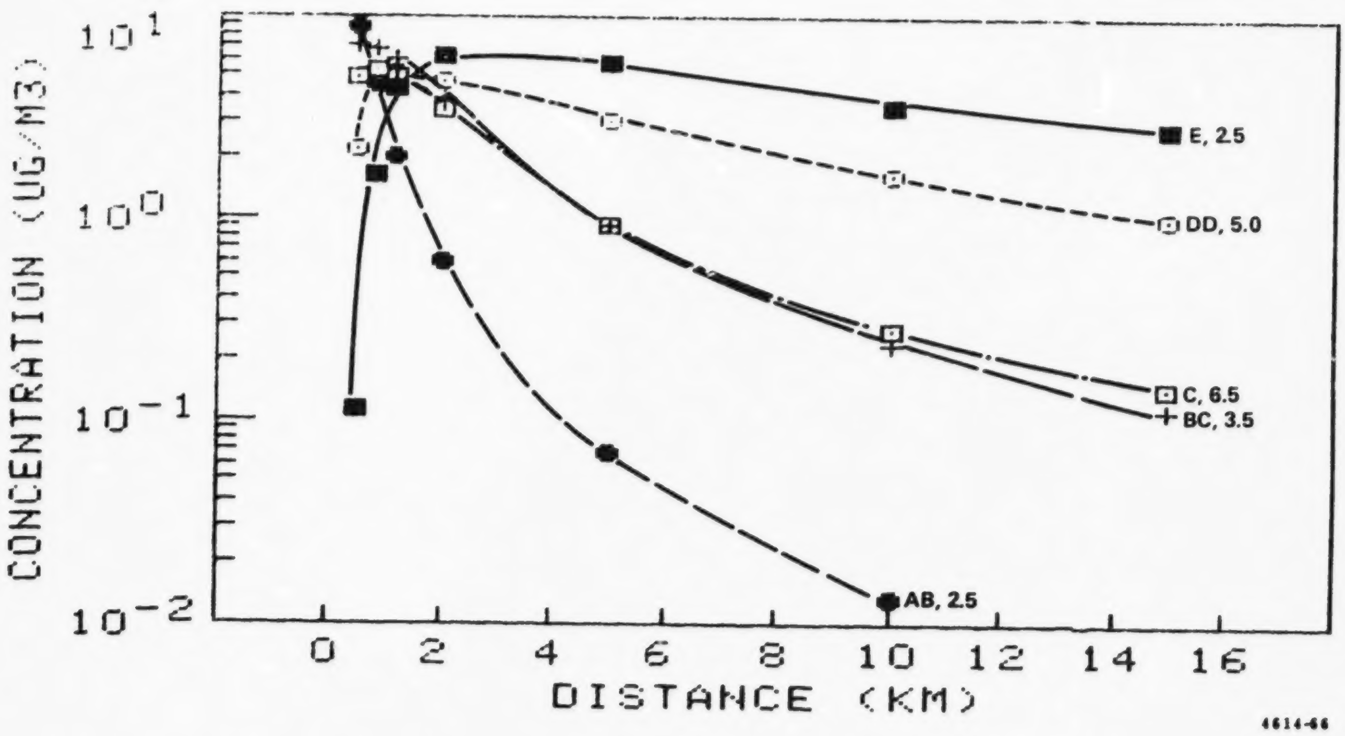

Figure 40. Union Camp 1 hour average sulfate concentrations (all sources). Letter and number combinations refer to stability classes and wind speeds.

times comparable to those used in the field sampling during this program would be somewhat lower - about one-half of those illustrated. It should be noted that the acid plant contributes only about ten percent (10%) of the projected sulfate concentrations shown in Figure 39.

Measured sulfate concentrations are compared to model predictions for "typical" conditions through the tests in Figures 41 and 42. The model predictions are again based on one-hour averaging times and are thus about twice what would be expected for the actual sampling times used in obtaining the measured points shown. As can be seen from the figures, the plants would have significant impacts only at distances from about 1 to 3 km immediately downwind of them. (Assuming an increase in concentration over the background of 10% to be significant.) It is apparent from Figures 31 and 42 that the measured upwind and crosswind sulfate concentrations are comparable to the downwind concentrations. In fact, for the case of the sampling in the vicinity of the pulpmill, the average downwind sulfate concentration was slightly lower than the average upwind concentration. As can be seen, the measured concentrations downwind of either plant range from about two to ten fold greater than the conservative predictions illustrated. In other words, realistically, the plants' contributions to the measured downwind sulfate concentrations might be in the range of five to twenty-five percent of the totals in the case of Cyanamid, and one to ten percent in the case of Union Camp. Only ten percent of the potential contribution from Cyanamid would originate from the acid plant.

The acid plant complex would not be expected to produce a measurable concentration of NO_x downwind, given the very low source emission rates. This might not be the case for the pulp mill, however. Figure 43 illustrates the measured average NO_x concentrations versus downwind distance from the pulp mill, together with diffusion model predictions for typical conditions during the tests. It is apparent that the measured concentrations are much higher than the predicted, even using the conservative Holland plume rise model. Therefore we conclude that the plants had no significant impact on local NO_x concentrations. Although not shown, similar results were obtained for SO_2.

The source impacts were discussed in the previous paragraphs in terms of their effects immediately downwind. However, the plumes from the plant are typically only five to twenty degrees wide, thus at any one time, the affected area around a source is only a small portion of its total surroundings. If the concentrations are averaged over 360° around the plant, the dispersion model predictions for sulfate concentrations shown in Figures 39 and 40 become those shown in Figures 44 and 45. If the wind rose for the area were uniform, the curves in these figures would roughly represent the expected annual average concentrations downwind of each source. At distances greater than about two to

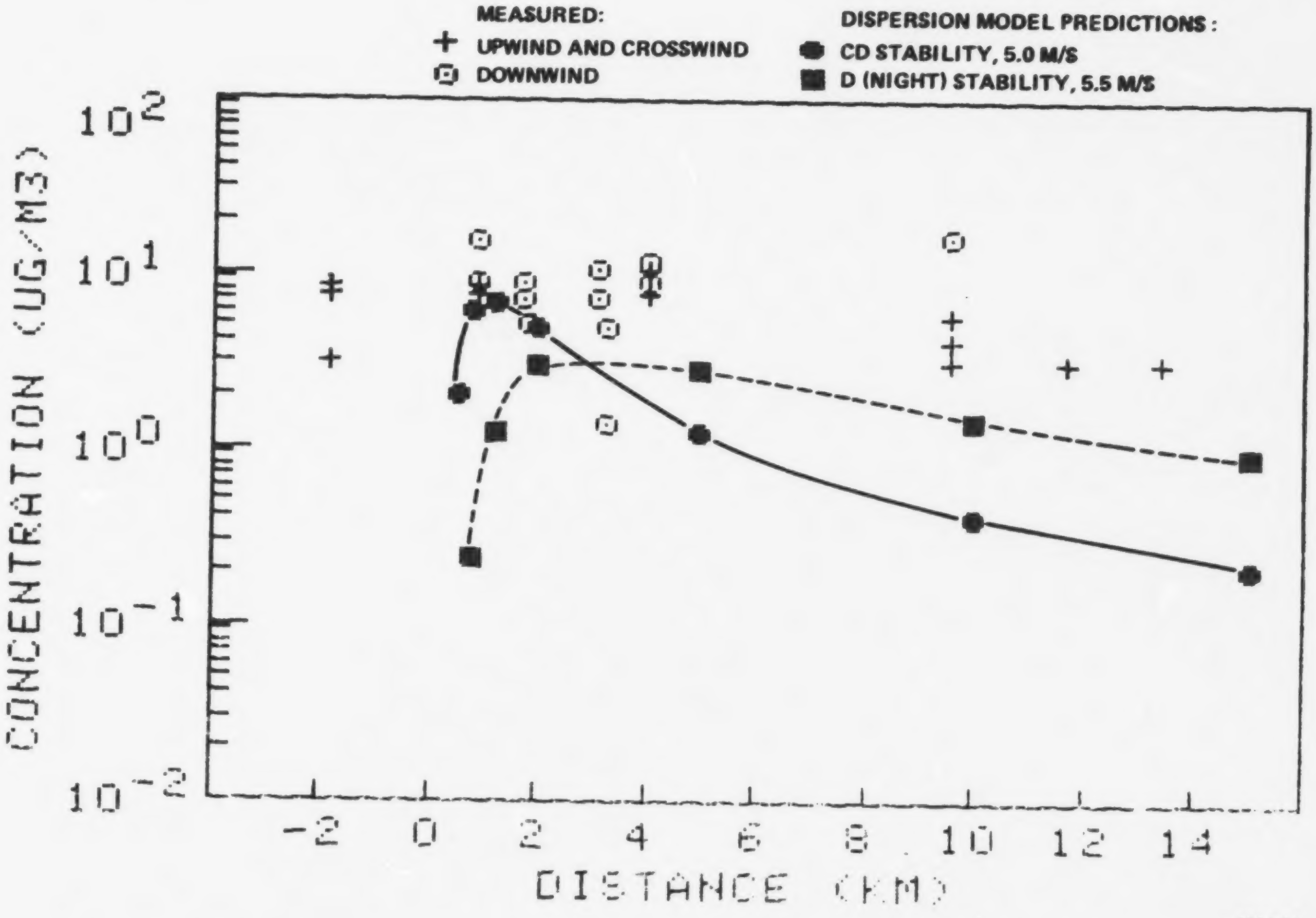

Figure 41. Cyanamid sulfate concentrations vs. downwind distance.

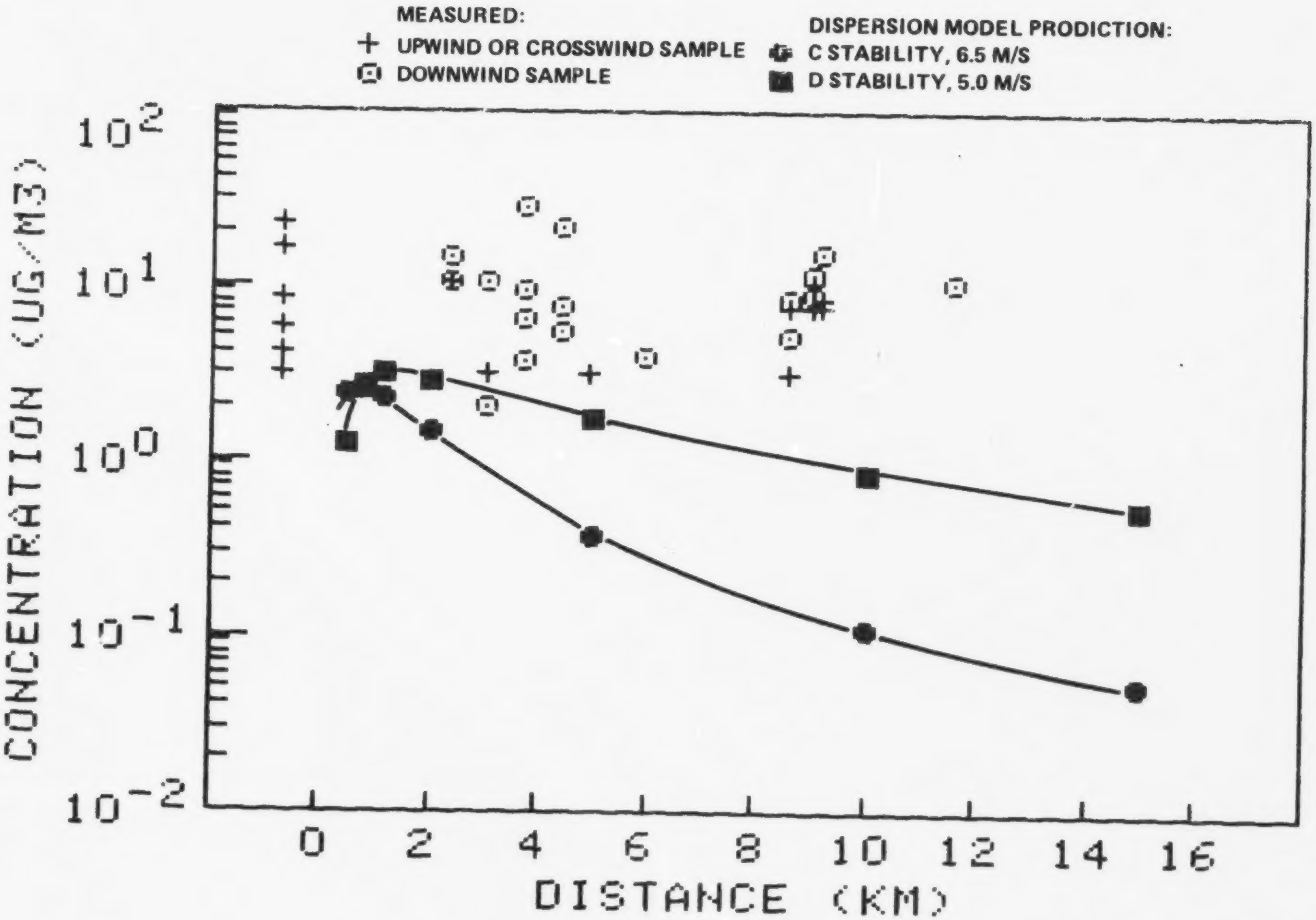

Figure 42. Union Camp sulfate concentrations vs. downwind distance.

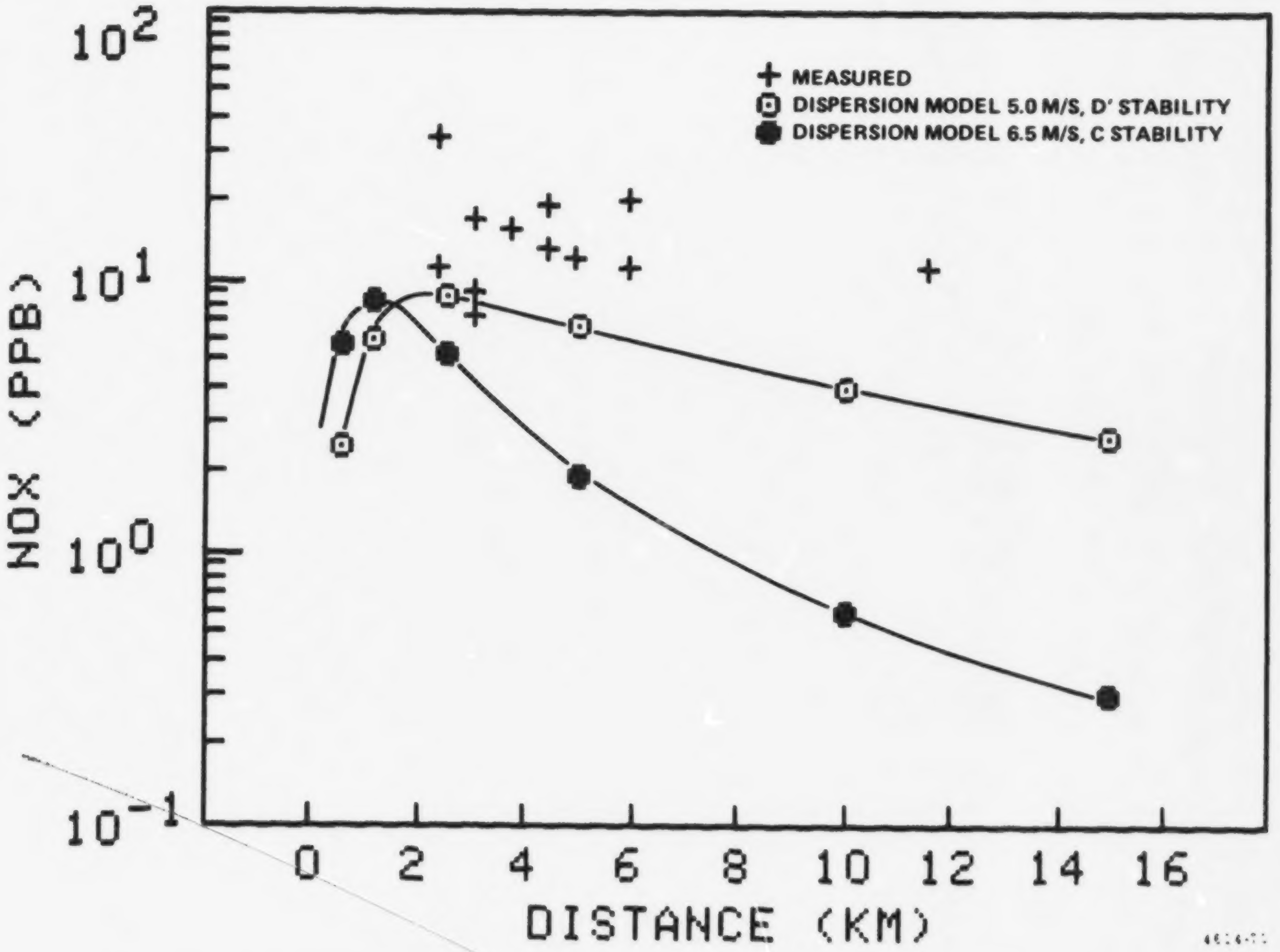

Figure 43. Comparison of NO_X concentrations measured downwind of Union Camp with dispersion model concentration predictions for the sum of all NO_X sources at Union Camp.

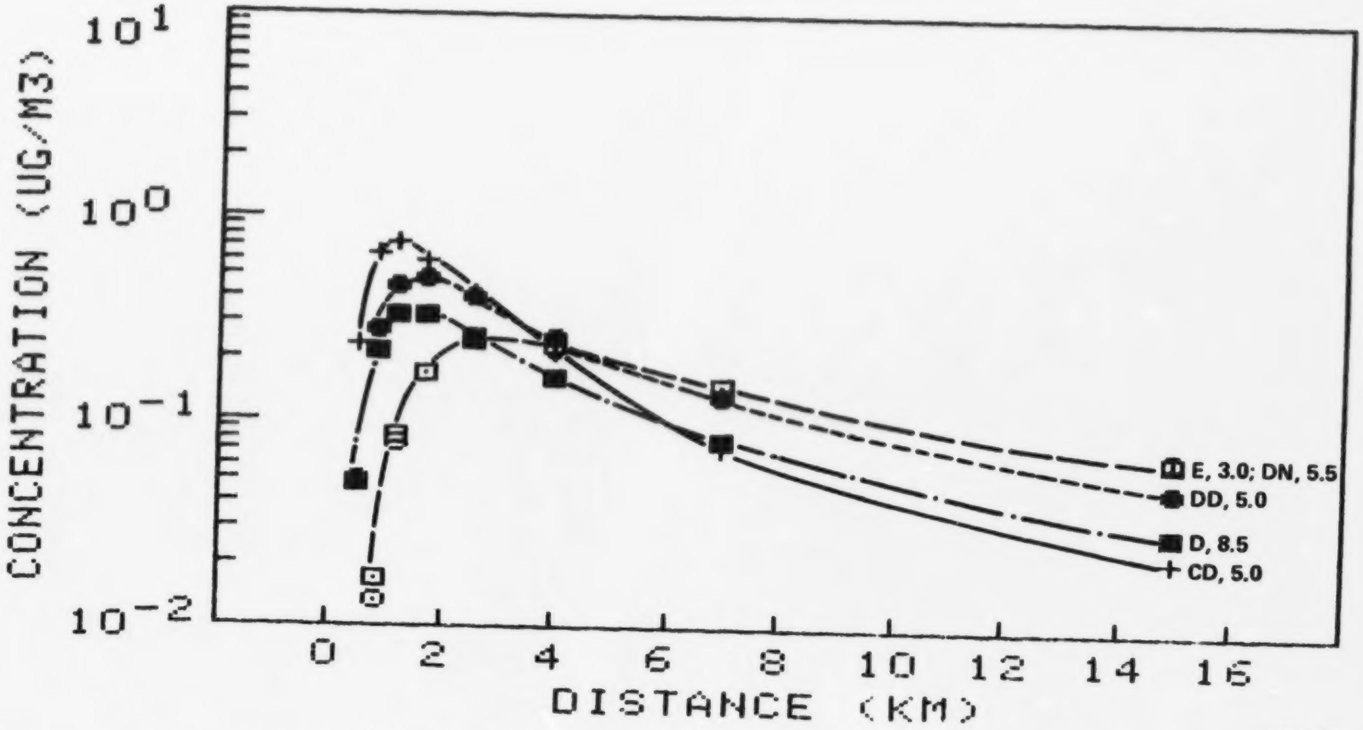

Figure 44. *Cyanamid concentration averaged over 360⁰ [net impact vs. distance from plant] based on 10 minute average concentration. Letters and numbers refer to stability classes and wind speeds.*

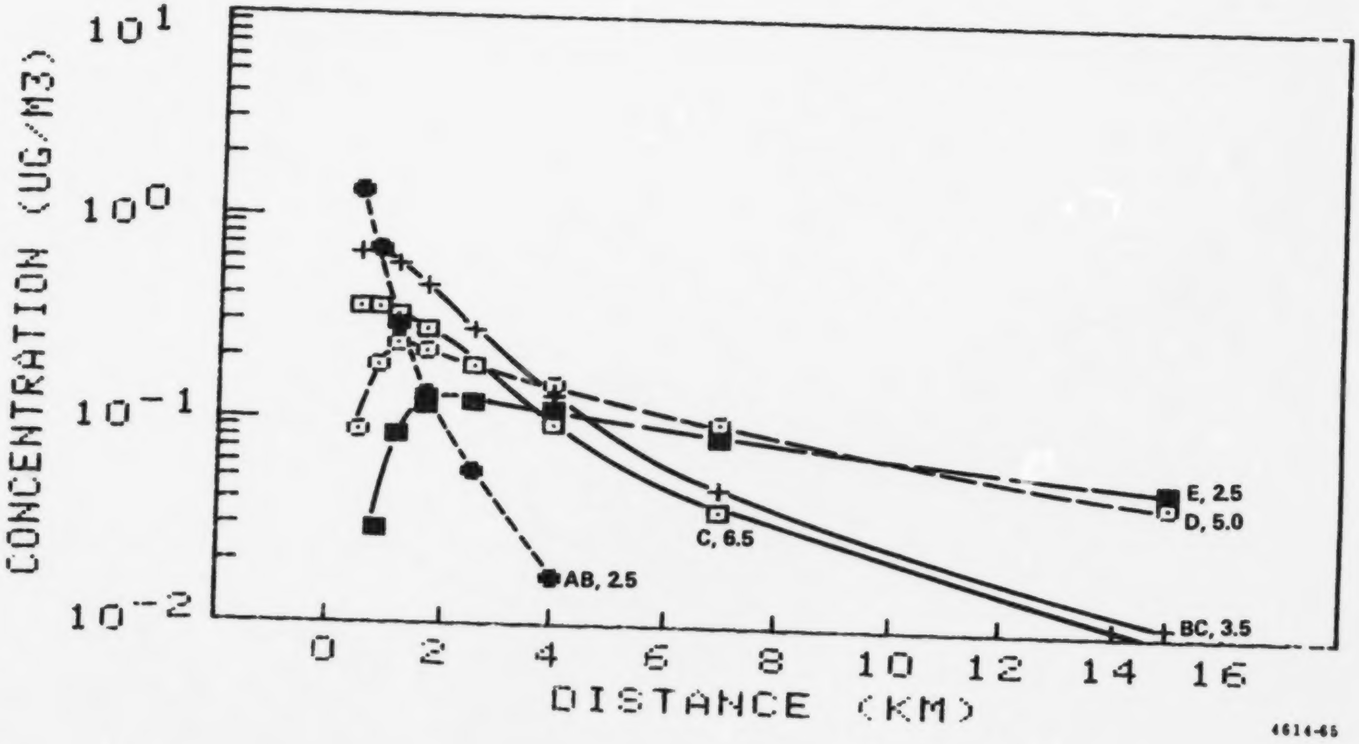

*Figure 45. Union Camp sulfate, all sources, downwind concentrations averaged over 360°
[net average impact vs. distance from plant] based on 10 minute average concentration.
Letters and numbers refer to stability classes and wind speeds.*

three kilometers the incremental additions to the background concentrations would be quite small. However, in the one to three kilometer range the effect would be significant - approximately eight to fifteen percent of the measured average ambient concentrations found during these tests.

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APPENDIX A

PLANT OPERATIONS INFORMATION

TABLE A-1. UNION CAMP RECOVERY BOILER OPERATIONS SUMMARY

DATE	NO. 12		NO. 13		NO. 14	
	STEAM, LBS/HR	BLS FIRING RATE LBS/HR	STEAM, LBS/HR	BLS FIRING RATE LBS/HR	STEAM, LBS/HR	BLS FIRING RATE LBS/HR
8/18	182.2	89.40	219.3	91.80	535.2	189.80
8/19	253.1	94.40	230.1	93.60	544.1	190.20
8/20	230.3	95.00	224.9	94.10	536.7	189.80
8/21	226.3	93.60	223.3	93.50	477.2	168.80
8/22	234.3	93.10	219.3	94.80	473.2	175.90
8/23	235.1	95.00	225.4	95.10	531.7	189.80
8/24	230.4	93.30	NA	NA	550.1	190.00
8/25	NA	NA	NA	NA	NA	NA
8/26	210.9	87.70	187.6	76.40	540.6	189.90
8/27	51.6*	28.6*	209.9	85.80	516.8	190.10
8/28	13.8*	34.0*	228.1	94.00	502.9	190.00

* UNIT DOWN MOST OF DAY

NOTE: BLS = BLACK LIQUOR SOLIDS

TABLE A-2. UNION CAMP LIME KILN OPERATIONS SUMMARY

DATE	GAS FIRING RATE, MCF/HR		
	NO.4	NO.5	NO.6
8/18	79.7	DOWN	90.5
8/19	79.4	DOWN	92.9
8/20	81.7	68.3 (16HR)	93.2
8/21	77.5	72.9	87.7
8/22	76.2	77.6	85.4
8/23	79.5	87.8	91.1
8/24	74.1	82.4	77.1(8HR)
8/25	83.1	90.8	DOWN
8/26	79.9	91.3	DOWN
8/27	71.9	91.1	36.4(8HR)
8/28	75.3	91.2	60.6

TABLE A-3. UNION CAMP POWER BOILER OPERATIONS SUMMARY

	NO. 10			NO. 11		NO. 12		NO.11 &12
DATE	OIL MLB/HR	GAS MCF/HR	STEAM MLB/HR	GAS MCF/HR	STEAM MLB/HR	GAS MCF/HR	STEAM MLB/HR	BARK, TPH
8/18	1.25	386	303.4	375	378.3	241	457.8	78
8/19	8.40	330	356.8	201	182.4	351	443.5	65
8/20		329	247.3	323	346.9	249	434.5	84
8/21	4.01	348	295.4	467	415.9	319	475.9	77
8/22	5.46	389	349.9	318	356.1	158	439.9	87
8/23		350	263.9	331	359.1	167	423.1	85
8/24		388	289.9	371	377.1	237	436.9	75
8/25		319	233.9	351	400.1	246	461.1	83
8/26	1.11	366	288.8	387	377.7	302	458.9	72
8/27	7.91	364	365.6	417	425.7	215	450.8	83
8/28		379	402.8	432	418.7	295	465.8	81

APPENDIX B

SOURCE FEED AND FUEL DATA

TABLE B-1. RESULTS OF NAA AND XRF ANALYSIS OF SULFUR FEED MATERIAL

	Sample # 1 99 % Sulfur		Sample # 2 95 % Sulfur	
	NAA	XRAY	NAA	XRAY
AL	1.53E+01	3.30E+04	9.53E+00	2.30E+04
SI	N.A.	1.66E+04	N.A.	9.90E+03
P	N.A.	2.69E+04	N.A.	N.D.
S	N.A.	2.74E+05	N.A.	3.31E+05
CL	1.45E+01	3.40E+03	2.49E+01	N.A.
K	N.A.	4.00E+01	N.A.	4.00E+01
CA	N.A.	N.D.	N.A.	N.D.
TI	5.49E+01	3.50E+02	8.29E+01	2.00E+01
V	3.10E-01	N.A.	5.30E-01	N.A.
CR	N.D.	N.A.	N.D.	N.A.
MN	1.78E+00	N.A.	8.20E-01	N.A.
FE	1.96E+02	N.D.	2.02E+01	N.D.
CO	N.D.	N.A.	N.D.	N.A.
NI	N.A.	N.D.	N.A.	N.D.
CU	N.A.	N.D.	N.A.	N.D.
ZN	3.70E+01	N.D.	N.A.	N.D.
GA	N.A.	N.D.	N.A.	N.D.
GE	N.A.	N.D.	N.A.	N.D.
AS	N.D.	N.A.	N.D.	N.A.
SE	N.D.	N.A.	N.D.	1.00E+02
BR	N.D.	N.A.	6.00E-02	2.00E+02
RB	N.A.	N.D.	N.A.	N.D.
SR	N.A.	N.D.	N.A.	N.D.
ZR	N.A.	N.D.	N.A.	N.D.
PB	N.A.	N.D.	N.A.	6.00E+02
HG	N.D.	N.A.	N.D.	N.A.
W	N.D.	N.A.	N.D.	N.A.
CD	N.D.	N.A.	N.D.	N.A.
SN	N.D.	N.A.	N.D.	N.A.
SB	N.D.	N.A.	N.D.	N.A.
BA	N.A.	N.D.	N.A.	N.D.
I	N.D.	N.A.	N.D.	N.A.
MG	N.D.	N.A.	1.02E+01	N.A.
NA	1.55E+01	N.A.	1.44E+01	N.A.
SM	N.D.	N.A.	N.D.	N.A.
CE	N.D.	N.A.	N.D.	N.A.
U	1.40E-01	N.A.	N.D.	N.A.
TH	N.D.	N.A.	N.D.	N.A.
LA	N.D.	N.A.	N.D.	N.A.
AU	N.D.	N.A.	N.D.	N.A.
AG	N.D.	N.A.	N.D.	N.A.
SC	N.D.	N.A.	N.D.	N.A.
EU	N.D.	N.A.	N.D.	N.A.
CS	N.D.	N.A.	N.D.	N.A.
MO	N.D.	N.A.	N.D.	N.A.
LU	N.D.	N.A.	N.D.	N.A.

All units are micrograms/gram.

Note: A source of systematic error inherent in the x-ray fluorescence technique is self-absorption of emitted x-rays, which makes the technique sensitive only to the upper few microns of the irradiated sample.[54-56] If the sample is too thick and particularly if it is non-uniform in thickness, the concentrations will be underestimated, particularly for elements lighter than potassium. Redispersion of bulk samples generally results in light loadings, yet corrections for the absorption within particles of larger size (>10 μm) are still needed for the lighter elements. The values reported here for sulfur are known to be low, probably as a result of self-absorption.

TABLE B-2. RECOVERY BOILER BLACK LIQUOR ULTIMATE ANALYSIS
(DRY BASIS)

BOILER: DATE:	NO. 12 8/18	NO. 12 8/29	NO. 14 8/18
% CARBON	28.74	21.55	21.06
% HYDROGEN	6.50	6.02	6.19
% NITROGEN	0.20	0.30	0.38
% CHLORINE	0.25	0.27	0.27
% SULFUR	2.32	2.16	2.33
% ASH	0.96	30.10	31.28
BTU/LB	NA	3782	3803

TABLE B-3. POWER BOILER BARK FEED ULTIMATE AND PROXIMATE ANALYSES

ULTIMATE ANALYSIS (DRY BASIS)

DATE:	8/24	8/24	8/27
% CARBON	56.66	58.92	57.41
% HYDROGEN	5.07	5.00	4.99
% NITROGEN	0.53	0.41	0.51
% CHLORINE	0.24	0.12	0.26
% SULFUR	1.71	1.19	1.49
% ASH	2.01	1.88	2.65

PROXIMATE ANALYSIS

DATE	8/24		8/24		8/24	
	WET	DRY	WET	DRY	WET	DRY
% MOISTURE	52.51		30.90		51.53	
% VOLATILE	35.41	74.56	46.28	66.97	35.54	73.33
% FIXED CARBON	11.13	23.43	21.52	31.15	11.65	24.02
BTU/LB	4168	8776	6377	9228	4304	8880

TABLE B-4. RESULTS OF NAA AND XRF ANALYSIS OF LIME KILN MUD SAMPLES

	Lime Kiln # 4 Aug. 19		Lime Kiln # 4 Aug. 27		Lime Kiln # 5 Aug. 22	
	NAA	XRAY	NAA	XRAY	NAA	XRAY
AL	2.00E+03	7.10E+04	1.83E+03	7.17E+04	2.22E+03	4.96E+04
SI	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
P	N.A.	4.90E+03	N.A.	1.70E+03	N.A.	N.D.
S	N.A.	1.49E+04	N.A.	1.48E+04	N.A.	1.36E+04
CL	3.60E+02	3.70E+03	N.D.	2.70E+03	4.01E+02	4.00E+02
K	N.A.	1.51E+04	N.A.	1.35E+04	N.A.	1.14E+04
CA	4.02E+04	2.97E+05	4.30E+04	2.96E+05	3.89E+04	2.79E+05
TI	1.35E+03	2.80E+02	N.A.	2.70E+02	N.A.	1.10E+02
V	N.D.	7.00E+01	7.68E+00	N.A.	N.D.	N.A.
CR	8.33E+01	N.A.	9.29E+01	N.A.	9.03E+01	N.A.
MN	8.26E+02	2.00E+03	7.62E+02	2.30E+03	9.76E+02	2.40E+03
FE	2.53E+03	5.60E+03	2.73E+03	5.80E+03	2.62E+03	6.10E+03
CO	1.93E+01	N.A.	2.34E+01	N.A.	2.34E+01	N.A.
NI	1.09E+01	N.D.	1.20E+01	N.D.	1.17E+01	1.00E+02
CU	N.A.	1.00E+02	N.A.	1.00E+02	N.A.	2.00E+02
ZN	2.00E+02	6.00E+02	2.43E+02	6.00E+02	2.55E+02	8.00E+02
GA	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
GE	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
AS	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
SE	N.D.	N.A.	N.D.	1.00E+02	N.D.	N.A.
BR	7.40E-01	N.A.	N.D.	1.00E+02	N.D.	N.A.
RB	2.70E+00	N.D.	3.44E+00	N.D.	2.83E+00	N.D.
SR	N.A.	5.30E+02	N.A.	5.60E+02	N.A.	5.90E+02
ZR	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
PB	N.A.	N.D.	N.A.	N.D.	N.A.	3.00E+02
HG	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
W	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
CD	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
SN	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
SB	3.00E-02	N.A.	7.00E-02	N.A.	3.00E-02	N.A.
BA	2.71E+02	4.00E+02	2.59E+02	4.00E+02	2.56E+02	6.00E+02
I	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
MG	3.24E+03	N.A.	2.75E+03	N.A.	4.49E+03	N.A.
NA	1.03E+04	N.A.	6.86E+03	N.A.	1.06E+04	N.A.
SM	2.00E-01	N.A.	2.30E-01	N.A.	2.20E-01	N.A.
CE	3.11E+00	N.A.	3.93E+00	N.A.	3.30E+00	N.A.
U	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
TH	2.30E-01	N.A.	2.90E-01	N.A.	2.80E-01	N.A.
LA	2.84E+00	N.A.	3.25E+00	N.A.	3.00E+00	N.A.
AU	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
AG	6.00E-01	N.A.	8.30E-01	N.A.	9.40E-01	N.A.
SC	2.30E-01	N.A.	2.70E-01	N.A.	2.40E-01	N.A.
EU	2.00E-02	N.A.	4.00E-02	N.A.	3.00E-02	N.A.
CS	1.00E-01	N.A.	9.00E-02	N.A.	5.00E-02	N.A.
MO	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
LU	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.

* All units are micrograms/gram .

TABLE B-5. RESULTS OF NAA AND XRF ANALYSIS OF RECOVERY BOILER BLACK LIQUOR SAMPLES

	Boiler # 12 Aug. 18		Boiler # 14 Aug. 18		Boiler # 12 Aug. 24	
	NAA	XRAY	NAA	XRAY	NAA	XRAY
AL	1.08E+03	N.A.	N.D.	N.A.	N.D.	N.A.
SI	N.A.	8.00E+02	N.A.	1.00E+03	N.A.	7.00E+02
P	N.A.	2.00E+02	N.A.	2.00E+02	N.A.	N.D.
S	N.A.	1.17E+01	N.A.	1.30E+04	N.A.	1.36E+04
CL	3.00E+03	1.00E+03	4.20E+03	1.40E+03	3.52E+03	1.10E+03
K	N.A.	4.95E+03	N.A.	5.17E+03	N.A.	5.15E+04
CA	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
TI	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
V	N.D.	N.A.	1.34E+01	N.A.	N.D.	N.A.
CR	N.D.	N.A.	3.70E-01	N.A.	6.60E-01	N.A.
MN	3.84E+01	N.A.	3.14E+01	N.A.	4.21E+01	2.00E+02
FE	5.09E+01	N.D.	5.21E+01	N.D.	7.06E+01	N.D.
CO	1.80E-01	N.A.	N.D.	N.A.	1.50E-01	N.A.
NI	9.40E-01	N.D.	N.A.	N.D.	N.A.	N.D.
CU	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
ZN	5.78E+00	N.D.	5.40E+00	4.00E+02	5.03E+00	1.00E+02
GA	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
GE	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
AS	N.D.	4.00E+02	N.D.	N.A.	N.D.	N.A.
SE	N.D.	2.00E+02	N.D.	2.00E+02	N.D.	3.00E+02
BR	8.09E+00	3.00E+02	7.75E+00	1.00E+02	9.65E+00	N.A.
RB	4.78E+01	N.D.	4.53E+01	N.D.	5.63E+01	N.D.
SR	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
ZR	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
PB	N.A.	N.D.	N.A.	N.D.	N.A.	N.D.
HG	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
W	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
CD	N.D.	N.A.	N.D.	N.A.	N.D.	6.00E+02
SN	N.D.	4.00E+02	N.D.	3.00E+02	N.D.	5.00E+02
SB	2.40E-01	N.A.	2.40E-01	N.A.	4.90E-01	4.00E+02
BA	N.A.	6.00E+02	1.29E+01	9.00E+02	2.30E+01	1.40E+03
I	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
MG	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
NA	1.05E+05	N.A.	9.84E+04	N.A.	1.14E+05	N.A.
SM	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
CE	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
U	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
TH	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
LA	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
AU	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
AG	2.20E-01	N.A.	N.D.	N.A.	N.D.	N.A.
SC	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.
EU	N.D.	N.A.	N.D.	N.A.	1.00E-02	N.A.
CS	1.01E+00	N.A.	9.00E-01	N.A.	N.D.	N.A.
MO	N.D.	N.A.	N.D.	N.A.	1.44E+00	N.A.
LU	N.D.	N.A.	N.D.	N.A.	N.D.	N.A.

* All units are micrograms/gram .

TABLE B-6. RESULTS OF NAA AND XRF ANALYSIS OF BARK SAMPLES

	Bark Aug. 18		Bark Aug. 27	
	NAA	XRAY	NAA	XRAY
AL	1.33E+03	3.60E+03	1.51E+03	2.00E+03
SI	N.A.	1.28E+04	N.A.	4.50E+03
P	N.A.	2.00E+02	N.A.	2.00E+02
S	N.A.	8.00E+02	N.A.	5.00E+02
CL	1.10E+02	2.00E+02	6.54E+01	1.00E+02
K	N.A.	9.40E+02	N.A.	1.23E+03
CA	6.44E+02	4.46E+03	7.32E+02	4.05E+03
TI	1.35E+02	5.00E+01	1.66E+02	6.00E+01
V	2.15E+00	N.A.	1.59E+00	1.00E+01
CR	6.85E+00	N.A.	1.86E+00	N.A.
MN	6.60E+01	N.A.	5.69E+01	2.00E+02
FE	1.08E+03	6.00E+02	5.84E+02	6.00E+02
CO	4.10E-01	N.A.	3.40E-01	N.A.
NI	N.A.	1.00E+02	N.A.	N.D.
CU	N.A.	N.D.	N.A.	N.D.
ZN	2.41E+01	2.00E+02	1.80E+01	N.D.
GA	N.A.	N.D.	N.A.	N.D.
GE	N.A.	N.D.	N.A.	N.D.
AS	N.D.	N.A.	N.D.	N.A.
SE	4.90E-01	N.A.	3.20E-01	N.A.
BR	1.35E+00	1.00E+02	9.10E-01	N.A.
RB	8.11E+00	N.D.	6.30E+00	N.D.
SR	N.A.	N.D.	N.A.	N.D.
ZR	N.A.	N.D.	N.A.	N.D.
PB	N.A.	3.00E+02	N.A.	N.D.
HG	3.40E-01	N.A.	1.50E-01	N.A.
W	N.D.	N.A.	N.D.	N.A.
CD	N.D.	N.A.	N.D.	N.A.
SN	N.D.	2.00E+02	N.D.	N.A.
SB	1.00E-01	N.A.	1.50E-01	N.A.
BA	4.86E+01	4.00E+02	4.88E+01	N.D.
I	N.D.	N.A.	N.D.	N.A.
MG	5.37E+02	N.A.	3.41E+02	N.A.
NA	2.24E+02	N.A.	1.76E+02	N.A.
SM	1.60E-01	N.A.	7.00E-02	N.A.
CE	1.53E+00	N.A.	1.48E+00	N.A.
U	2.60E-01	N.A.	1.40E-01	N.A.
TH	2.50E-01	N.A.	2.40E-01	N.A.
LA	8.80E-01	N.A.	9.30E-01	N.A.
AU	N.D.	N.A.	N.D.	N.A.
AG	N.D.	N.A.	N.D.	N.A.
SC	1.70E-01	N.A.	1.10E-01	N.A.
EU	5.00E-02	N.A.	5.00E-02	N.A.
CS	3.40E-01	N.A.	3.50E-01	N.A.
MO	N.D.	N.A.	N.D.	N.A.
LU	N.D.	N.A.	N.D.	N.A.

* All units are micrograms/gram .

APPENDIX C

METEOROLOGICAL DATA

TABLE C-1A. SAVANNAH METEOROLOGICAL DATA FOR AUGUST 11 THROUGH AUGUST 16

	DATE: 8/11					DATE: 8/12					DATE: 8/15					DATE: 8/16				
TIME	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %
0						1.79	343									2.91	171			
1						2.24	111									2.24	197			
2						1.12	240									2.24	283			
3						0.89	120									2.01	300			
4						1.34	231									2.24	257			
5						2.24	257									2.68	249			
6						3.13	257									3.13	257			
7						2.68	274									2.68	249			
8						2.68	283									3.35	257			
9						3.13	274	24								3.58	253			
10						3.13	291									3.58	261			
11						3.58	274									3.13	266	30	0	57
12						3.13	283	32	15		1.34	351		0		3.35	267		0	
13			32	20		3.13	257				2.91	86				3.13	273			
14			33	20		2.24	351				3.13	103				1.79	300			
15	4.92	103	33	20		1.34	154	34	30		3.80	94				1.79	283	35	15	47
16	4.92	111				4.92	68				3.13	94				1.79	274			
17	4.47	120				7.15	146				3.58	103	30	0		5.81	197	33	15	56
18	4.47	146				5.81	186				4.47	129	30	0		6.26	180	31	0	59
19	4.02	154				1.79	240				4.02	163	29	0		5.36	180	29	10	70
20	3.13	163									3.13	163	28	0		4.25	180	29		69
21	2.68	189									2.68	154				4.69	180			
22	2.24	214									2.91	154				4.47	180			
23	2.24	283									2.68	154				4.02	189			

TABLE C-1B. SAVANNAH METEOROLOGICAL DATA FOR AUGUST 17 THROUGH AUGUST 22

	DATE: 8/17					DATE: 8/18					DATE: 8/20					DATE: 8/22				
TIME	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %
0	3.58	197		0		6.71	26													
1	3.80	197				6.26	26													
2	3.58	214				5.14	13													
3	3.13	231				6.26	9													
4	2.46	240				6.71	17													
5	2.68	300				8.05	17													
6	2.91	351				8.49	26				3.58	347		100						
7	2.24	360				8.05	26				3.58	351		100						
8	2.24	309				7.60	34				5.36	360		100						
9	3.13	274				8.05	26				5.36	9		100						
10	3.13	266				8.05	34				4.92	17	22	100	84	3.13	360			
11	2.24	291				7.60	39	31	50		3.80	360		100		3.35	360		75	
12	1.34	343	31	0	60	8.72	34				3.13	360	23	100	78	3.35	360			
13	2.01	86	33		56	9.39	26				2.91	360	23	100	81	3.13	360			
14	3.58	146				8.49	26				2.68	360	24	100		2.68	10			
15	4.47	94	33	25	61	7.60	30				2.68	360	23	100	78	2.24	16	28	80	62
16	5.36	86	31	10		7.38	17				3.35	360	23	100	78	2.91	43	31		
17	6.26	94			63	6.71	9				4.02	360		100		4.02	26	30	80	62
18	5.36	103	30	75	66	7.60	13				3.58	8	22	100	83	3.13	47	28	60	69
19	4.47	103	29	100	72	6.71	13				4.02	17	22	100	85	2.24	73			
20	3.58	86									4.02	21		100		2.01	86			
21	3.13	77									4.47	30		100		2.24	86			
22	3.35	69									4.47	34		100		2.24	90			
23	4.47	34									4.92	34		100		2.24	69			

TABLE C-1C. SAVANNAH METEOROLOGICAL DATA FOR AUGUST 23 THROUGH AUGUST 26

	DATE: 8/23					DATE: 8/24					DATE: 8/25					DATE: 8/26				
TIME	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %
0	2.46	77				3.13	335				1.56	270				0.67	180			
1	2.24	81				3.58	344				1.34	300				0.89	90			
2	1.79	77				4.47	344				1.56	306				1.34	22			
3	1.79	60				4.47	360				1.79	310				1.79	5			
4	2.24	43				5.14	340				1.79	280				2.24	360			
5	2.68	34				4.47	34				1.79	300				2.01	360			
6	2.68	26				3.13	16				1.56	324				1.79	355			
7	2.91	34				3.13	360				1.34	288				2.24	12			
8	3.13	26				4.02	16				1.34	295				3.13	36			
9	2.91	26				4.02	25	22	30	82	1.79	315				3.58	45			
10	4.92	17				3.35	7				3.13	345				5.59	63	27	0	78
11	4.69	21	24	100	77	3.58	360	24	15	73	3.13	360				6.03	72			
12	4.25	17		100R		3.58	16				3.58	360				6.71	90			
13	4.92	21	24	100	81	4.02	25				3.35	360	31	0	55	6.93	90			
14	4.92	8	23		84	3.80	43				2.91	351	32	0	57	6.71	85	29	20	58
15	5.36	360				4.47	25	29	10	52	1.79	342				7.15	81			
16	5.59	352	24	80	78	3.58	34			49	1.34	355	34	10	48	7.15	90			
17	5.36	360	24	80	73	4.02	100	30	0		1.79	360	32	10	52	6.93	81			
18	4.25	360	24	80		5.14	136				4.02	110				5.81	72	27		60
19	3.13	16				4.02	144				3.13	108				4.69	85	27	15	72
20	2.68	360				3.13	153				2.24	220				4.02	85			
21	2.46	344				3.13	162				2.01	180				3.58	75			
22	2.24	352				2.24	180				1.34	184				3.13	54			
23	2.46	352				1.34	234				0.89	190				2.46	18			

TABLE C-1D. SAVANNAH METEOROLOGICAL DATA FOR AUGUST 27

DATE: 8/27

TIME	SPEED M/S	DIR. DEG.	TEMP. DEG C	CLOUD COVER	R.H. %
0	2.46	23			
1	2.24	20			
2	2.24	18			
3	2.24	18			
4	2.24	9			
5	2.24	20			
6	1.79	23			
7	2.24	18	22	15	68
8	2.68	20			
9	2.91	32	24	80	45
10	3.58	21			
11	4.02	36	27	90	36
12	4.02	54			
13	4.02	40			
14	4.25	59			
15	4.02	55	28	90	34
16	4.25	68			
17	5.14	98			

APPENDIX D

AMBIENT DATA

TABLE D-1. AMBIENT SO_2 CONCENTRATIONS FROM BUBBLER SAMPLES

DATE	SITE	START TIME	END TIME	SO2 PPB	EST. P.E.	FILTER ID
8/11	1	1848	1949	428	222	626
8/12	3	1327	1548	352	96	630
8/16	5	1920	2014	275	160	603
	3	1134	1948	284	79	602
	2	1334	2027	344	83	601
8/17	3	1037	1715	95	23	633
		1715	1820	312	128	633
	5	1543	1930	36	14	635
8/18	3	1216	1508	114	52	641
		1515	1714	22	62	641
8/20	7	1127	1552	9	30	645
		1559	1806	74	74	648
		1812	2041	0	48	648
	6	1218	1302	0	181	644
		1308	1402	0	94	644
		1408	1610	0	87	644
		1617	1828	0	64	644
		1836	1952	0	96	644
	5	1431	1640	35	69	646
		1648	2117	0	30	646
8/22	11	1342	1725	33	39	604
		1731	1923	30	74	604
	14	1500	1744	86	44	606
		1753	2003	12	58	606
	8	1611	1850	99	54	639
8/23	12	1017	1313	11	43	605
		1317	1858	31	24	605
	10	1107	1340	84	63	624
		1356	1617	79	70	624
	8	1227	2012	9	22	623
8/24	13	955	1135	25	62	618
		1139	1420	19	42	618
		1427	1600	10	65	640
		1605	1737	16	77	640
	11	1105	1341	44	40	622
		1345	1637	8	37	621
	8	1235	1454	9	35	619
8/25	14	1305	1529	37	47	616
		1536	1712	41	81	616
	11	1408	1600	96	54	615
		1605	1749	33	82	615
	8	1458	1639	92	76	617
8/26	8	1123	2105	36	12	614
	10	1355	1655	65	59	613
		1700	1855	30	45	613
		1905	2212	60	37	613
	9	1622	2033	35	26	625
8/26-27	8	2110	2548	35	23	612
		153	612	23	23	612
		619	1414	18	15	612
	9	2038	2426	45	33	611
		31	342	22	34	611
	10	2217	2638	47	29	610
		242	826	18	16	610
		830	1134	51	37	610
8/27	15	453	758	27	35	609
		803	1252	29	30	609

TABLE D-2. AMBIENT PARTICLE SIZE DISTRIBUTIONS

HI-VOL IMPACTOR DATA

Date	Site	Percent less than size indicated .95	 1.5	 3.0	 7.2
8/15	2	50.1	63.8	72.4	87.1
8/16	2	65.8	73.5	73.5	87.7
8/17	2	62.4	77.4	77.4	100
	4	68.5	81.6	81.6	100
8/20	5	57.0	68.4	68.4	85.4
8/22	14	64.2	64.2	71.7	84.5
8/24	14	79.4	79.4	79.4	88.5
	14	76.6	76.6	76.6	87.6
8/25	14	62.9	72.5	79.2	87.6
8/26	9	65.8	65.8	65.8	84.5
	10	50.3	50.3	59.2	77.4
	8	65.6	75.5	75.5	90.8

LUNDGREN IMPACTOR DATA

Date	Site	Percent less than size indicated .3	 1.0	 3.0	 10.
8/11	1	6	30	58	72
8/12	5	6	25	49	77
	3	6	34	52	74
8/15	2	18	47	72	81
	4	5	36	55	73
	4	13	33	50	83
8/16	2	10	36	53	78
	5	5	5	36	62
	4	11	42	65	65
8/17	2	9	31	53	79
	4	16	48	48	78
	5	4	33	53	74
8/18	4	7	34	60	80
8/20	7	13	31	74	74
	6	15	30	53	80
	5	7	34	49	76
8/22	14	3	29	29	69
	11	8	22	34	76
	8	8	51	67	69
8/23	12	29	54	83	83
	10	17	42	56	64
	8	23	23	54	62
8/24	13	10	22	31	91
	11	7	19	27	78
	8	15	37	49	68
8/26	9	13	43	60	78
	10	14	47	67	82
	8	11	27	38	81
8/27	15	17	29	48	71

TABLE D-3A. ELEMENTAL CONCENTRATIONS FOR THE AMBIENT HI-VOL FILTERS

	36601	36602	36603	36604	36605	36606	36609	36610	36611	36612
Al	5.67E-01	2.84E-01	2.98E-01	5.25E+00	3.04E-01	7.41E-01	4.55E-01	1.30E+00	1.68E+00	2.24E-01
Si	1.53E+00	7.17E-01	5.96E-01	1.76E+01	8.39E-01	1.79E+00	1.23E+00	4.35E+00	1.95E+00	4.71E-01
P	2.34E-01	2.83E-02	4.36E-02	6.74E-02	3.26E-02	4.72E-02	4.02E-02	3.84E-02	3.26E-02	N.D.
S	5.12E+00	3.90E+00	2.80E+00	1.21E+00	1.01E+00	1.25E+00	3.49E+00	3.38E+00	3.48E+00	2.80E+00
Cl	1.57E-01	8.78E-02	5.02E-01	4.15E-01	1.79E-01	2.05E-01	2.98E-01	1.80E-01	3.73E-01	3.18E-01
K	2.57E-01	1.34E-01	7.76E-02	1.15E+00	8.81E-02	2.92E-01	3.59E-01	4.55E-01	2.86E-01	1.60E-01
Ca	3.94E-01	3.90E-01	1.35E-01	1.52E+00	7.76E-02	3.26E-01	8.18E-01	1.76E+00	7.81E-01	1.85E-01
Ti	5.73E+00	7.43E-02	3.81E-02	3.81E-01	2.95E-02	2.55E-02	1.79E-02	1.36E-01	7.59E-02	N.D.
V	9.61E-03	3.81E-03	4.33E-03	8.06E-03	2.13E-03	2.29E-03	1.13E-02	2.48E-02	1.06E-02	4.69E-03
Cr	2.93E-03	1.37E-03	N.D.	5.96E-03	N.D.	2.82E-03	3.89E-03	7.10E-03	3.97E-03	2.88E-03
Mn	7.72E-03	4.19E-03	2.82E-03	2.09E-02	2.41E-03	7.58E-03	8.68E-03	6.38E-03	8.35E-03	4.24E-03
Fe	1.21E+00	2.85E-01	5.94E-01	3.20E+00	2.72E-01	5.72E-01	4.85E-01	9.69E-01	4.48E-01	1.87E-01
Co	2.82E-04	8.83E-05	7.76E-05	6.47E-04	8.15E-06	4.25E-04	2.91E-04	3.16E-04	3.16E-04	8.21E-05
Ni	1.30E-02	N.D.	N.D.	N.D.	N.D.	1.46E-02	2.07E-02	1.97E-02	4.63E-02	N.D.
Cu	1.17E+00	1.39E-01	1.15E+00	2.58E-01	2.75E-01	5.26E-01	5.42E-01	2.13E-01	2.56E-01	4.31E-01
Zn	4.10E-02	2.09E-02	1.53E-02	N.D.	1.25E-02	3.97E-02	3.40E-02	5.59E-02	2.10E-02	2.96E-02
As	N.D.	N.D.	1.21E-03	1.54E-03	N.D.	N.D.	N.D.	2.35E-03	N.D.	9.20E-04
Se	2.45E-03	3.49E-04	2.53E-04	6.24E-04	5.63E-04	N.D.	1.49E-03	7.10E-04	3.32E-03	3.57E-04
Br	2.77E-03	8.15E-03	3.21E-03	2.35E-02	8.34E-03	1.91E-02	4.35E-03	2.95E-02	6.24E-03	7.33E-03
Rb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sr	1.34E-01	3.08E-02	N.D.	1.54E-01	N.D.	N.D.	N.D.	1.91E-02	1.58E-01	N.D
Zr	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pb	N.D.	4.10E-02	1.82E-01	1.43E-01	N.D.	2.84E-01	1.58E-01	1.21E-01	N.D.	N.D.
Hg	1.73E-03	9.98E-04	N.D.	3.10E-03	2.44E-03	1.88E-03	2.58E-03	N.D.	3.41E-03	N.D.
W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cd	4.61E-03	3.85E-03	6.05E-03	9.43E-03	6.23E-04	8.24E-03	4.44E-04	4.37E-03	3.53E-03	9.62E-04
Sn	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sb	2.06E-03	5.39E-04	4.02E-04	1.11E-03	5.55E-05	3.90E-03	2.43E-03	4.77E-04	2.88E-03	3.67E-04
Ba	6.67E-02	6.14E-03	N.D.	4.25E-02	2.36E-01	N.D.	9.74E-03	9.69E-02	N.D.	9.35E-02
I	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Mg	1.02E-01	6.56E-02	4.78E-02	3.94E-01	5.59E-02	6.79E-02	6.48E-02	2.18E-01	3.61E-01	6.07E-02
Na	1.57E-01	4.83E-01	7.15E-02	5.88E-01	1.80E-01	1.81E-01	6.73E-01	1.39E+00	9.18E-01	1.16E+00
Sm	4.44E-05	5.02E-05	5.08E-05	6.78E-04	4.08E-05	1.75E-04	7.57E-05	2.16E-04	2.55E-04	2.71E-05
Ce	4.41E-04	1.67E-02	6.37E-02	8.27E-01	6.65E-02	7.29E-04	5.74E-04	2.65E-01	1.50E-03	2.50E-02
U	N.D.	N.D.	N.D.	5.46E-04	N.D.	N.D.	1.47E-04	1.29E-04	N.D.	N.D.
Th	1.09E-04	5.52E-05	8.46E-05	1.32E-03	N.D.	1.32E-04	1.15E-04	5.14E-04	4.00E-04	3.73E-05
La	2.88E-04	2.99E-04	5.15E-04	4.54E-03	2.23E-04	4.35E-04	3.44E-04	1.67E-03	1.28E-03	1.56E-04
Au	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Ag	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sc	2.14E-04	7.27E-05	5.88E-05	9.36E-04	4.23E-05	1.27E-04	9.42E-05	2.90E-04	1.90E-04	5.12E-05
Eu	6.91E-06	6.34E-06	1.49E-05	1.67E-04	N.D.	9.79E-06	N.D.	5.53E-05	N.D.	N.D.
Cs	1.26E-04	N.D.	N.D.	N.D.	N.D.	2.59E-04	2.27E-04	N.D.	2.02E-04	N.D.
Mo	2.18E-01	N.D.	N.D.	2.27E-01	N.D.	N.D.	N.D.	4.04E-01	2.75E-01	N.D.
Lu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NA	1.52E+00	1.41E+00	1.47E+00	N.R.	6.81E-01	4.58E-01	1.06E+00	1.61E+00	4.72E-01	1.30E+00
N3	3.01E-01	4.37E-01	1.01E-01	6.52E-01	7.50E-02	2.76E-01	6.23E-01	6.45E-01	7.09E-01	4.16E-01
Ms	7.83E+01	5.20E+01	3.83E+01	2.03E+02	1.98E+01	3.59E+01	3.24E+01	8.79E+01	5.49E+01	8.50E+01
S4	8.25E+00	8.47E+00	6.15E+00	1.59E+00	1.75E+00	2.03E+00	6.85E+00	8.02E+00	6.92E+00	6.65E+00
MASS AS OXIDES	3.63E+01	2.18E+01	1.43E+01	1.38E+02	3.90E+01	9.08E+01	4.18E+01	5.90E+01	1.75E+02	1.43E+01
EDXRF S AS SULFATE	1.53E+01	1.17E+01	8.40E+00	3.62E+00	3.04E+00	3.75E+00	1.05E+01	1.01E+01	1.04E+01	8.41E+00

All units are micrograms/M3 .

N.R. - Not Reported , and N.D. - Not Detected .

(continued)

TABLE D-3A (continued)

	36613	36614	36615	36616	36617	36618	36619	36621	36622	36623
Al	1.77E+00	2.55E-01	7.60E+00	1.05E+00	5.21E-01	1.00E+00	1.01E-01	1.73E+01	6.55E+00	1.39E-01
Si	3.41E+00	6.93E-01	3.04E+01	2.18E+00	1.20E+00	6.55E+00	3.58E-01	6.28E+01	2.77E+01	1.59E-01
P	1.17E-01	2.27E-02	1.55E-01	5.29E-02	2.61E-02	3.06E-02	1.64E-02	2.28E-01	1.32E-01	3.09E-02
S	6.70E-01	5.45E+00	9.09E+00	6.90E+00	7.24E+00	2.45E+00	1.88E+00	3.14E+00	2.14E+00	1.03E+00
Cl	8.64E-01	9.89E-02	3.02E-01	2.15E-01	1.35E-01	1.44E-01	1.10E-01	5.58E-01	1.78E-01	6.99E-02
K	3.33E-01	1.55E-01	2.21E+00	3.92E-01	1.60E-01	5.79E-01	2.85E-02	3.71E+00	1.80E+00	5.66E-02
Ca	5.56E-01	2.01E-01	4.72E+00	8.11E-01	2.54E-01	1.23E+00	7.16E-02	6.64E+00	3.13E+00	1.93E-02
Ti	9.21E-02	2.51E-02	8.13E-01	9.12E-02	4.16E-02	1.39E-01	9.28E-03	1.46E+00	5.82E-01	1.22E-02
V	8.27E-03	5.06E-03	1.65E-02	7.95E-03	2.52E-03	2.04E-03	1.62E-03	2.64E-02	1.08E-02	2.74E-03
Cr	3.37E-03	1.18E-03	1.13E-02	5.04E-03	6.08E-04	7.83E-03	N.D.	1.87E-02	1.28E-02	1.52E-03
Mn	1.43E-02	4.55E-03	4.50E-02	1.69E-02	4.73E-03	1.26E-02	7.99E-04	8.91E-02	3.67E-02	1.73E-03
Fe	1.46E+00	1.75E-01	7.50E+00	7.22E-01	3.82E-01	2.53E+00	6.23E-02	1.17E+01	5.47E+00	1.00E-01
Co	4.59E-04	1.28E-04	1.40E-03	4.42E-04	5.45E-05	6.70E-04	N.D.	4.10E-03	1.26E-03	8.61E-06
Ni	1.49E-02	8.18E-03	N.D.	1.86E-02	N.D.	N.D.	N.D.	4.53E-02	N.D.	N.D.
Cu	1.21E-01	9.24E-02	3.59E-01	2.79E-01	4.41E-01	4.07E-01	1.76E-01	1.82E-01	1.80E-01	1.59E-01
Zn	7.53E-02	1.78E-02	1.55E-01	4.10E-02	1.83E-02	1.72E-01	8.46E-03	7.72E-02	1.44E-01	9.47E-03
As	N.D.	N.D.	N.D.	N.D.	1.31E-03	5.50E-04	2.97E-04	N.D.	3.75E-03	N.D.
Se	3.86E-03	1.98E-03	4.40E-03	2.88E-03	1.21E-03	4.22E-03	2.54E-04	N.D.	9.08E-03	6.06E-04
Br	6.75E-03	2.79E-03	4.91E-03	4.92E-04	4.16E-03	9.96E-03	2.61E-03	1.21E-02	1.99E-02	6.63E-04
Rb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sr	N.D.	N.D.	9.42E-01	9.71E-01	3.22E-01	1.00E+00	1.82E-01	N.D.	N.D.	N.D.
Zr	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pb	1.40E-01	N.D.	4.62E-01	8.10E-01	5.81E-01	1.00E+00	2.88E-01	1.38E+00	7.61E-01	3.58E-01
Hg	1.64E-03	1.48E-03	7.45E-03	1.45E-03	N.D.	3.31E-03	N.D.	1.97E-02	3.09E-03	1.19E-03
W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cd	7.63E-03	3.23E-03	5.15E-03	3.75E-03	6.57E-04	1.78E-02	2.36E-03	3.05E-03	2.19E-02	4.59E-04
Sn	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sb	4.56E-03	3.42E-03	3.30E-02	3.17E-03	3.25E-04	1.72E-04	8.42E-05	5.55E-02	4.57E-03	1.60E-03
Ba	1.45E-01	N.D.	8.79E-02	4.14E-01	3.27E-01	3.65E-02	N.D.	1.70E-01	3.40E-01	N.D.
I	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Mg	1.87E-01	8.25E-02	7.31E-01	1.75E-01	9.17E-02	1.01E-01	N.D.	1.07E+00	1.06E+00	4.88E-03
Na	7.48E-01	7.40E-01	N.D.	N.D.	4.03E+01	5.20E-01	1.00E-01	7.26E-01	5.39E-01	N.D.
Sm	2.00E-04	1.82E-05	7.75E-04	4.89E-05	5.73E-05	2.12E-04	1.33E-05	2.20E-03	8.82E-04	6.57E-06
Ce	1.79E-03	1.65E-04	N.D.	1.52E-03	1.10E-01	4.48E-01	2.11E-02	1.66E-02	1.42E+00	N.D.
U	1.88E-04	N.D.	1.38E-03	N.D.	4.74E-05	1.53E-04	4.35E-05	2.07E-03	7.95E-04	N.D.
Th	3.28E-04	1.58E-05	1.41E-03	2.32E-04	9.94E-05	7.72E-04	2.47E-05	3.00E-03	2.18E-03	N.D.
La	1.30E-03	1.34E-04	3.47E-03	2.14E-04	4.18E-04	1.78E-03	3.11E-05	1.15E-02	6.00E-03	1.04E-04
Au	N.D.	1.90E-05	1.15E-03	2.92E-04	N.D.	N.D.	N.D.	N.D.	N.D.	1.01E-04
Ag	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	9.32E-05
Sc	2.59E-04	3.27E-05	1.27E-03	2.57E-04	1.17E-04	4.59E-04	1.40E-05	2.07E-03	1.52E-03	7.45E-06
Eu	3.25E-05	4.76E-06	2.65E-04	N.D.	2.37E-05	N.D.	N.D.	6.24E-04	N.D.	N.D.
Cs	3.64E-04	N.D.	N.D.	2.51E-04	N.D.	N.D.	N.D.	3.98E-03	N.D.	1.58E-04
Mo	N.D.	1.37E-01	1.54E+00	1.64E+00	5.84E-01	1.67E+00	2.08E-01	3.81E-01	N.D.	N.D.
Lu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NA	1.69E+00	3.25E+00	2.84E+00	2.69E+00	6.02E+00	N.R.	1.08E+00	3.23E-01	6.71E-01	7.53E-01
N3	1.50E+00	2.01E-01	1.17E+00	3.14E-01	3.62E-01	4.19E-01	N.R.	6.47E-01	7.82E-01	7.50E-02
Ms	8.79E+01	1.89E+02	2.72E+02	6.16E+01	2.50E+02	5.53E+01	2.02E+01	3.99E+02	1.90E+02	1.77E+01
S4	4.13E+00	1.46E+01	1.89E+01	1.39E+01	1.74E+01	4.34E+00	3.93E+00	4.61E+00	3.33E+00	1.38E+00
MASS AS OXIDES	4.01E+01	2.00E+01	1.73E+02	1.05E+02	1.37E+02	1.04E+02	7.74E+00	2.70E+02	1.24E+02	4.67E+00
EDXRF S AS SULFATE	2.01E+00	1.63E+01	2.73E+01	2.07E+01	2.17E+01	7.36E+00	5.65E+00	9.42E+00	6.43E+00	3.09E+00

* All units are micrograms/M3 .
N.R. - Not Reported , and N.D. - Not Detected .

(continued)

TABLE D-3A (continued)

	36624	36625	36626	36627	36628	36630	36631	36633	36634	36635
Al	4.66E-01	1.56E+00	1.24E+00	9.29E-01	1.15E+00	1.03E+00	7.47E-01	7.64E-01	2.66E-01	4.53E-01
Si	1.09E+00	4.67E+00	2.89E+00	1.02E+00	1.99E+00	2.15E+00	1.48E+00	1.60E+00	6.93E-01	1.26E+00
P	3.13E-02	4.08E-02	3.10E-01	9.93E-02	3.18E-02	6.56E-02	6.53E-02	3.09E-02	4.00E-02	1.60E-02
S	1.05E+00	4.73E+00	2.98E+00	1.02E+00	4.53E-01	1.58E+00	1.65E+00	2.91E+00	2.90E+00	2.64E+00
Cl	4.79E-02	8.03E-01	3.64E+00	1.11E+00	1.71E+00	7.61E-01	4.21E-01	1.21E-01	1.55E-01	2.83E-01
K	1.12E-01	6.13E-01	3.18E-01	1.24E-01	1.61E-01	3.01E-01	3.25E-01	3.51E-01	2.15E-01	1.81E-01
Ca	1.20E-01	1.36E+00	8.18E-01	3.66E-01	6.62E-01	6.85E-01	8.35E-01	9.09E-01	3.01E-01	4.83E-01
Ti	4.42E-02	8.50E-02	7.57E+00	2.87E-02	1.77E-01	1.56E-01	9.28E-02	2.08E-01	9.54E-01	3.39E-01
V	2.95E-03	1.99E-02	1.58E-02	2.39E-03	2.57E-03	4.95E-03	5.64E-03	1.02E-02	9.29E-03	9.73E-03
Cr	1.82E-03	2.88E-03	7.68E-03	2.32E-03	1.14E-03	3.21E-03	2.46E-03	1.65E-03	9.73E-04	2.38E-03
Mn	3.83E-03	1.03E-02	1.40E-02	7.65E-03	1.60E-02	1.15E-02	1.09E-02	8.76E-03	3.76E-03	6.26E-03
Fe	3.62E-01	1.05E+00	2.34E+00	5.99E-01	8.13E-01	7.38E-01	5.69E-01	6.89E-01	2.41E-01	5.56E-01
Co	7.34E-05	2.87E-04	5.12E-04	N.D.	4.39E-05	1.19E-04	1.94E-04	2.90E-04	9.97E-05	3.52E-04
Ni	N.D.	N.D.	3.70E-02	N.D.	N.D.	2.96E-02	N.D.	N.D.	N.D.	N.D.
Cu	9.43E-02	1.23E-01	2.82E-01	3.41E-01	3.29E-01	1.97E-01	2.81E-01	1.25E-01	5.14E-01	7.48E-01
Zn	2.82E-02	4.68E-02	7.93E-02	7.13E-02	4.25E-02	2.82E-02	7.04E-02	2.60E-02	1.50E-02	3.04E-02
As	N.D.	N.D.	2.07E-03	N.D.	1.36E-03	N.D.	N.D.	7.17E-04	N.D.	N.D.
Se	3.08E-04	6.12E-04	N.D.	N.D.	N.D.	1.37E-03	8.16E-04	7.97E-04	5.59E-04	N.D.
Br	2.78E-03	2.71E-02	1.45E-03	1.03E-02	6.92E-04	1.61E-03	2.56E-03	7.96E-03	1.04E-03	2.47E-03
Rb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sr	N.D.	2.91E-01	2.61E-01	N.D.	N.D.	8.51E-01	N.D.	2.34E-01	1.13E-01	2.42E-01
Zr	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pb	4.47E-01	3.27E-01	1.41E+00	7.91E-01	1.48E+00	1.01E+00	5.86E-01	5.20E-01	1.63E-01	4.31E-01
Hg	2.03E-03	3.12E-03	1.02E-02	1.32E-02	7.66E-03	4.86E-03	3.73E-03	N.D.	9.63E-04	1.59E-03
W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cd	1.74E-02	6.72E-03	1.75E-02	1.51E-02	2.90E-01	1.20E-02	9.95E-03	4.14E-02	3.49E-04	6.68E-03
Sn	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sb	1.48E-03	9.19E-04	5.52E-03	6.50E-04	5.84E-03	2.38E-03	2.08E-03	2.29E-04	1.17E-03	2.60E-03
Ba	5.42E-03	2.20E-02	N.D.	3.92E-03	5.78E-01	N.D.	7.55E-03	5.60E-03	1.36E-02	7.66E-03
I	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Mg	9.83E-02	2.24E-01	1.14E-01	1.09E-01	2.61E-01	1.85E-01	8.34E-02	1.43E-01	3.67E-02	4.94E-02
Na	N.D.	2.36E+00	4.10E-01	1.06E+00	N.D.	N.D.	N.D.	3.71E-01	N.D.	2.41E-01
Sm	2.88E-05	2.60E-04	2.81E-04	8.82E-05	1.01E-04	7.92E-05	1.04E-04	8.73E-05	3.33E-05	9.87E-05
Ce	N.D.	3.33E-01	8.17E-04	9.28E-02	1.33E-03	3.98E-04	N.D.	1.62E-01	N.D.	N.D.
U	N.D.	N.D.	3.71E-04	N.D.	N.D.	N.D.	1.14E-04	N.D.	7.68E-05	8.64E-05
Th	8.57E-05	3.94E-04	5.61E-04	1.17E-04	1.12E-04	2.41E-05	2.23E-04	2.12E-04	5.99E-05	1.69E-04
La	1.45E-04	1.59E-03	8.47E-04	5.99E-04	3.80E-04	3.66E-04	3.89E-04	7.91E-04	1.24E-04	4.28E-04
Au	1.28E-04	N.D.	N.D.	2.51E-04	3.56E-04	2.29E-04	5.88E-04	N.D.	5.22E-05	9.97E-05
Ag	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.32E-04	N.D.	7.38E-05	N.D.
Sc	1.27E-04	2.50E-04	6.13E-04	1.00E-04	3.11E-04	4.85E-05	1.22E-04	1.52E-04	4.79E-04	1.06E-04
Eu	N.D.	2.50E-05	2.18E-05	2.25E-05	N.D.	N.D.	2.63E-05	N.D.	3.07E-06	N.D.
Cs	N.D.	N.D.	3.37E-04	N.D.	1.43E-04	2.02E-04	1.69E-04	N.D.	9.06E-05	9.46E-05
Mo	N.D.	4.68E-01	5.15E-01	1.61E-01	N.D.	1.08E+00	N.D.	2.56E-01	1.14E-01	3.96E-01
Lu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NA	8.93E-01	1.24E+00	1.73E+00	4.46E-01	2.60E+00	2.50E+00	1.44E+00	1.75E+00	1.45E+00	N.R.
N3	7.40E-02	2.00E+00	6.92E-01	5.56E-01	1.95E+00	4.70E-01	5.95E-01	5.00E-01	2.61E-01	N.R.
Ms	2.52E+01	5.49E+01	8.01E+01	6.34E+01	6.18E+01	3.05E+02	2.51E+02	8.47E+01	1.40E+02	2.19E+02
S4	1.41E+00	1.11E+01	4.03E+00	8.60E-01	9.00E-01	2.43E+00	2.33E+00	6.30E+00	5.73E+00	8.35E+00
MASS AS OXIDES	3.12E+01	8.88E+01	4.91E+01	2.81E+02	1.99E+01	2.17E+01	1.58E+01	2.14E+01	1.45E+01	1.77E+01
EDXRF S AS SULFATE	3.14E+00	1.42E+01	8.95E+00	3.05E+00	1.36E+00	4.74E+00	4.96E+00	8.73E+00	8.71E+00	7.93E+00

All units are micrograms/M3 .
N.R. - Not Reported , and N.D. - Not Detected .

(continued)

TABLE D-3A (continued)

	36636	36637	36638	36639	36640	36641	36644	36645	36646	36648
Al	N.D.	1.52E-01	1.86E-01	1.08E-01	1.27E+00	2.58E-01	2.84E-01	1.27E-01	1.07E+00	1.42E-01
Si	2.73E-01	3.55E-01	3.28E-01	1.25E-01	2.83E+00	4.38E-01	5.29E-01	3.50E-01	1.05E+01	1.74E-01
P	5.65E-02	3.74E-02	6.34E-02	1.49E-02	1.19E-02	2.11E-02	3.23E-02	2.41E-02	3.21E-02	3.26E-02
S	2.53E+00	3.51E-01	2.75E+00	1.33E+00	1.81E+00	2.44E+00	2.39E+00	2.40E+00	2.50E+00	3.38E+00
Cl	7.27E-02	2.70E-02	2.10E-01	1.42E-01	3.25E-01	1.11E-01	2.74E-01	9.66E-02	7.14E-02	1.18E-01
K	1.56E-01	1.70E-01	2.80E-01	3.21E-02	3.49E-01	1.07E-01	8.80E-02	2.24E-02	4.64E-01	2.40E-02
Ca	9.73E-02	1.26E-01	1.57E-01	4.18E-02	5.07E-01	1.36E-01	1.08E-01	3.40E-02	1.46E-01	8.10E-02
Ti	2.21E-02	1.62E-02	5.11E-02	1.08E-02	2.66E-02	3.35E-02	3.84E-01	2.15E-01	2.42E-01	3.36E-02
V	1.05E-02	1.20E-02	1.40E-02	1.08E-03	3.69E-03	1.17E-02	3.55E-03	2.21E-03	2.47E-03	1.35E-03
Cr	4.87E-04	9.27E-04	3.19E-03	1.64E-03	6.56E-03	3.30E-03	2.86E-03	2.25E-03	8.02E-03	4.23E-03
Mn	2.22E-03	2.34E-03	3.64E-03	1.19E-03	1.29E-02	3.96E-03	4.10E-03	1.43E-03	5.54E-03	1.36E-03
Fe	6.89E-02	1.73E-01	1.24E-01	9.34E-02	9.98E-01	1.44E-01	2.25E-01	1.48E-01	7.34E-01	1.16E-01
Co	7.33E-05	1.15E-04	2.73E-04	1.29E-04	4.46E-04	2.51E-04	3.70E-04	1.20E-04	2.72E-04	2.86E-04
Ni	N.D.	5.84E-04	2.25E-02	2.08E-02	5.38E-02	1.70E-02	3.22E-03	9.42E-03	N.D.	3.92E-02
Cu	1.83E-01	2.73E-01	1.01E-01	2.48E-01	4.54E-01	1.62E-01	3.47E-01	3.44E-01	4.96E-01	1.35E-01
Zn	1.35E-02	2.46E-02	1.62E-02	9.88E-03	3.33E-02	2.76E-02	2.11E-02	8.89E-03	5.06E-02	1.74E-02
As	N.D.	6.99E-04	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Se	6.50E-04	6.46E-04	3.69E-04	1.30E-03	2.16E-03	1.53E-03	1.64E-03	1.98E-03	8.21E-04	9.16E-04
Br	6.25E-03	5.12E-03	2.22E-03	1.39E-03	1.24E-02	2.28E-03	1.22E-03	1.84E-03	6.83E-04	3.49E-03
Rb	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sr	8.66E-02	1.87E-01	1.16E-01	2.38E-01	9.16E-01	N.D.	N.D.	N.D.	N.D.	N.D.
Zr	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pb	2.69E-01	2.84E-01	6.72E-01	9.31E-01	1.27E+00	7.55E-01	8.94E-01	7.28E-01	3.36E-01	1.61E+00
Hg	8.25E-04	N.D.	3.49E-03	2.92E-03	6.40E-03	1.84E-03	3.15E-03	4.28E-03	3.91E-03	5.85E-03
W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cd	1.06E-03	6.22E-02	2.02E-03	2.18E-03	6.72E-03	2.72E-02	2.28E-02	2.80E-03	1.29E-03	3.95E-03
Sn	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sb	3.69E-04	5.90E-04	5.56E-03	1.34E-03	4.26E-03	4.97E-03	1.95E-03	1.45E-03	1.64E-03	1.84E-03
Ba	9.96E-04	N.D.	N.D.	N.D.	3.76E-01	2.32E-03	5.27E-03	8.28E-03	3.20E-02	1.18E-02
I	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Mg	8.18E-02	6.66E-02	N.D.	5.56E-02	2.70E-01	7.74E-02	3.28E-02	7.20E-03	8.76E-02	N.D.
Na	7.30E-01	8.07E-01	2.97E-01	2.26E-01	2.76E-01	4.61E-01	N.D.	1.73E-02	N.D.	1.23E-02
Sm	1.69E-05	1.95E-05	1.02E-05	9.84E-06	2.15E-04	1.74E-05	3.65E-05	9.19E-06	1.06E-04	2.74E-04
Ce	1.82E-02	1.37E-02	N.D.	N.D.	1.08E-03	2.93E-04	6.30E-04	4.38E-04	1.04E-03	3.38E-03
U	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.41E-04	8.15E-05	N.D.
Th	6.68E-06	1.77E-05	N.D.	N.D.	2.00E-04	1.31E-05	2.32E-05	4.87E-06	1.28E-04	6.29E-04
La	1.03E-04	2.59E-04	1.85E-04	2.77E-05	9.24E-04	2.86E-04	2.98E-04	3.96E-04	5.42E-04	1.46E-03
Au	N.D.	N.D.	N.D.	N.D.	8.97E-04	1.13E-04	9.51E-05	N.D.	6.89E-05	N.D.
Ag	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	9.40E-05	N.D.
Sc	2.20E-05	2.39E-05	1.21E-05	1.12E-05	3.05E-04	2.75E-05	9.00E-06	3.21E-05	1.06E-04	N.D.
Eu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	2.51E-05	N.D.
Cs	N.D.	N.D.	3.89E-04	1.20E-04	4.28E-04	2.74E-04	8.78E-05	1.34E-04	1.28E-04	N.D.
Mo	1.33E-01	2.84E-01	2.29E-01	3.09E-01	1.36E+00	N.D.	N.D.	N.D.	3.00E-01	3.39E-01
Lu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NA	5.72E-01	2.92E+00	7.77E-01	7.89E-01	1.27E+00	8.10E-01	5.81E-01	6.36E-01	1.36E+00	2.22E+00
N3	1.63E-01	8.10E-02	7.77E-01	1.68E-01	1.80E-01	2.68E-01	N.R.	1.05E-01	5.90E-02	N.R.
Ms	2.80E+01	2.45E+01	3.86E+01	2.39E+01	2.55E+01	1.72E+02	3.18E+01	2.71E+01	5.89E+01	2.71E+01
S4	6.62E+00	8.13E+00	5.41E+00	6.88E+00	3.53E+00	4.48E+00	4.98E+00	5.12E+00	5.50E+00	6.55E+00
MASS AS OXIDES	1.09E+01	7.25E+00	1.23E+01	7.41E+00	1.42E+02	1.17E+01	1.17E+01	9.66E+00	3.84E+01	1.46E+02
EDXRF S AS SULFATE	7.59E+00	1.05E+00	8.25E+00	4.00E+00	5.44E+00	7.33E+00	7.17E+00	7.21E+00	7.49E+00	1.02E+01

* All units are micrograms/M3 .
N.R. - Not Reported , and N.D. - Not Detected .

TABLE D-3B. ERROR IN THE ELEMENTAL CONCENTRATIONS FOR THE AMBIENT HI-VOL FILTERS

	36601	36602	36603	36604	36605	36606	36609	36610	36611	36612
Al	2.93E-03	3.00E-03	3.42E-03	5.30E-02	1.38E-01	7.91E-03	2.47E-03	6.64E-03	2.10E-03	2.45E-03
Si	6.17E-02	6.02E-02	1.45E-01	2.09E-01	1.47E-01	1.79E-01	1.07E-01	8.37E-02	2.28E-01	7.61E-02
P	2.82E-02	2.25E-03	6.65E-02	7.82E-03	5.49E-03	6.67E-03	4.01E-03	3.13E-03	8.51E-03	3.48E-02
S	1.59E-02	1.55E-02	3.74E-02	5.38E-02	3.77E-02	4.59E-02	2.76E-02	2.15E-02	5.85E-02	1.96E-02
Cl	8.91E-03	5.48E-03	2.76E-02	2.44E-02	1.17E-02	1.35E-02	1.68E-02	1.05E-02	2.28E-02	1.72E-02
K	3.53E-03	3.44E-03	8.31E-03	1.20E-02	8.39E-03	1.02E-02	6.13E-03	4.78E-03	1.30E-02	4.35E-03
Ca	3.53E-03	3.44E-03	8.31E-03	1.20E-02	8.39E-03	1.02E-02	6.13E-03	4.78E-03	1.30E-02	4.35E-03
Ti	1.76E-03	1.72E-03	4.16E-03	5.98E-03	3.83E-03	5.10E-03	3.07E-03	2.39E-03	6.50E-03	2.17E-03
V	9.64E-05	3.84E-05	2.19E-04	8.19E-05	2.19E-04	2.35E-04	1.13E-04	2.48E-04	1.07E-04	4.73E-05
Cr	3.40E-04	1.85E-04	1.47E-04	7.61E-04	1.30E-04	4.30E-04	4.72E-04	3.90E-04	5.83E-04	3.47E-04
Mn	8.10E-05	4.67E-05	1.07E-04	2.23E-04	1.52E-04	9.43E-05	9.49E-05	7.02E-05	1.09E-04	4.93E-05
Fe	2.62E-02	2.55E-02	6.17E-02	8.87E-02	6.22E-02	7.57E-02	4.55E-02	3.55E-02	9.65E-02	3.23E-02
Co	3.31E-06	1.40E-06	2.15E-06	8.18E-06	5.99E-06	5.74E-06	3.80E-06	3.83E-06	5.15E-06	1.50E-06
Ni	4.43E-03	2.10E-03	3.66E-03	6.45E-03	3.69E-03	8.66E-03	5.79E-03	6.40E-03	1.26E-02	2.00E-03
Cu	1.32E-02	1.29E-02	3.12E-02	4.49E-02	3.15E-02	3.83E-02	2.30E-02	1.79E-02	4.88E-02	1.63E-02
Zn	2.12E-03	1.11E-03	1.85E-03	3.30E-04	1.57E-03	4.36E-03	1.82E-03	2.88E-03	1.34E-03	1.57E-03
As	N.D.	N.D.	6.06E-05	7.69E-05	N.D.	N.D.	N.D.	1.18E-04	N.D.	4.60E-05
Se	2.45E-05	1.74E-05	2.53E-05	3.12E-05	5.63E-05	N.D.	1.49E-05	3.55E-05	3.32E-05	1.78E-05
Br	5.97E-06	8.26E-05	3.72E-05	2.39E-04	8.69E-05	1.95E-04	2.26E-04	2.97E-04	3.31E-04	7.49E-05
Rb	1.29E-02	1.26E-02	3.05E-02	4.39E-02	3.08E-02	3.74E-02	2.25E-02	1.75E-02	4.77E-02	1.59E-02
Sr	9.25E-02	9.02E-02	2.70E-02	3.14E-01	2.73E-02	3.32E-02	1.99E-02	1.55E-02	3.41E-01	1.41E-02
Zr	1.23E-02	1.20E-02	2.91E-02	4.19E-02	2.94E-02	3.57E-02	2.15E-02	1.67E-02	4.55E-02	1.52E-02
Pb	4.32E-02	1.66E-01	4.00E-01	5.76E-01	1.03E-01	4.91E-01	2.95E-01	5.86E-02	1.59E-01	5.33E-02
Hg	8.83E-05	5.20E-05	9.23E-06	1.62E-04	1.27E-04	1.00E-04	1.32E-04	5.31E-06	1.78E-04	4.83E-06
W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cd	2.34E-04	1.96E-04	6.19E-04	4.83E-04	1.54E-04	1.68E-03	1.11E-04	4.44E-04	5.62E-04	5.49E-05
Sn	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sb	1.08E-04	3.24E-05	3.43E-05	7.49E-05	1.91E-05	4.43E-05	2.75E-05	3.16E-05	3.73E-05	2.55E-05
Ba	5.35E-02	3.88E-03	1.26E-01	1.35E-02	1.27E-01	1.55E-01	6.91E-03	7.26E-02	1.97E-01	6.60E-02
I	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Mg	1.58E-02	6.88E-03	8.38E-03	4.05E-02	9.58E-03	7.87E-03	7.09E-03	1.78E-02	3.73E-02	9.70E-03
Na	1.69E-03	2.47E-03	1.05E-03	6.27E-03	2.09E-03	2.18E-03	3.47E-03	7.04E-03	9.60E-03	1.17E-02
Sm	2.25E-06	2.54E-06	2.60E-06	3.40E-05	4.21E-06	1.77E-06	3.83E-06	1.08E-05	1.28E-05	1.39E-06
Ce	9.28E-05	2.51E-03	9.57E-03	8.27E-02	6.66E-03	1.93E-05	6.24E-05	1.32E-02	1.60E-04	2.51E-03
U	N.D.	N.D.	N.D.	5.46E-05	N.D.	N.D.	1.47E-05	1.29E-05	N.D.	N.D.
Th	1.14E-05	6.04E-06	1.45E-05	6.69E-05	1.21E-06	1.48E-05	1.24E-05	2.61E-05	4.19E-05	4.41E-06
La	8.94E-06	1.54E-05	1.61E-05	4.58E-05	1.23E-05	1.40E-05	1.80E-05	1.68E-05	6.55E-05	5.07E-06
Au	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Ag	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sc	1.09E-05	3.81E-06	6.72E-06	9.51E-06	4.08E-06	6.89E-06	1.09E-06	1.48E-05	2.21E-06	2.79E-06
Eu	1.04E-06	9.51E-07	1.49E-06	1.67E-05	N.D.	N.D.	N.D.	5.53E-06	N.D.	N.D.
Cs	5.56E-06	3.24E-06	7.82E-06	1.13E-05	7.89E-06	3.37E-05	1.45E-05	4.50E-06	1.87E-05	4.09E-06
Mo	1.26E-01	N.D.	N.D.	4.26E-01	N.D.	N.D.	N.D.	1.70E-01	4.63E-01	N.D.
Lu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NA	2.28E-01	2.12E-01	2.20E-01	N.R.	1.02E-01	6.87E-02	1.59E-01	2.41E-01	7.08E-02	1.95E-01
N3	4.52E-02	6.56E-02	1.51E-02	9.78E-02	1.13E-02	4.14E-02	9.35E-02	9.68E-02	1.06E-01	6.24E-02
Ms	1.57E+01	1.04E+01	7.66E+00	4.05E+01	3.96E+00	7.18E+00	6.48E+00	1.76E+01	1.10E+01	1.70E+01
S4	8.25E-01	8.47E-01	6.15E-01	1.59E-01	1.75E-01	2.03E-01	6.85E-01	8.02E-01	6.92E-01	6.65E-01

* All units are micrograms/M3 .
N.R. - Not Reported , and N.D. - Not Detected .

(continued)

TABLE D-3B (continued)

	36624	36625	36626	36627	36628	36630	36631	36633	36634	36635
Al	5.06E-03	1.62E-02	6.83E-03	9.88E-03	8.05E-03	5.74E-03	7.92E-03	8.07E-03	5.59E-03	4.88E-03
Si	1.44E-01	2.18E-01	3.37E-01	2.15E-01	4.19E-01	3.01E-01	1.64E-01	1.60E-01	5.60E-02	1.26E-01
P	5.37E-03	8.14E-03	1.54E-01	9.83E-02	1.56E-02	1.13E-02	6.12E-03	5.99E-03	2.56E-02	4.69E-03
S	3.69E-02	5.60E-02	8.66E-02	5.53E-02	1.08E-01	7.75E-02	4.21E-02	4.12E-02	1.44E-02	3.23E-02
Cl	5.44E-03	4.39E-02	3.80E-02	2.40E-02	9.24E-02	1.03E-02	9.96E-03	9.17E-03	3.62E-03	6.89E-03
K	8.20E-03	1.24E-02	1.93E-02	1.23E-02	2.39E-02	1.72E-02	9.36E-03	9.16E-03	3.20E-03	7.18E-03
Ca	8.20E-03	1.24E-02	1.93E-02	1.23E-02	2.39E-02	1.72E-02	9.36E-03	9.16E-03	3.20E-03	7.18E-03
Ti	3.75E-03	6.22E-03	9.63E-03	6.14E-03	1.09E-02	8.61E-03	4.68E-03	4.58E-03	1.60E-03	3.59E-03
V	1.50E-04	2.00E-04	1.60E-04	2.47E-04	3.26E-05	5.23E-05	2.85E-04	1.03E-04	9.32E-05	9.79E-05
Cr	3.03E-04	4.71E-04	1.04E-03	4.15E-04	5.11E-04	5.79E-04	3.82E-04	3.03E-04	1.43E-04	3.40E-04
Mn	5.72E-05	3.38E-04	1.76E-04	1.01E-04	2.06E-04	1.18E-04	1.22E-04	1.02E-04	4.22E-05	7.46E-05
Fe	6.08E-02	9.23E-02	1.43E-01	9.11E-02	1.77E-01	1.28E-01	6.94E-02	6.80E-02	2.37E-02	5.32E-02
Co	2.10E-06	4.78E-06	8.03E-06	2.24E-06	4.73E-06	4.10E-06	3.39E-06	4.26E-06	1.47E-06	4.55E-06
Ni	3.84E-03	5.48E-03	1.46E-02	5.40E-03	1.05E-02	1.55E-02	4.59E-03	4.03E-03	1.65E-03	4.14E-03
Cu	3.08E-02	4.67E-02	7.22E-02	4.61E-02	8.97E-02	6.46E-02	3.51E-02	3.44E-02	1.20E-02	2.69E-02
Zn	1.57E-03	5.14E-03	4.35E-03	3.80E-03	2.65E-03	1.79E-03	3.70E-03	2.95E-03	8.13E-04	1.66E-03
As	N.D.	N.D.	1.04E-04	N.D.	6.80E-05	N.D.	N.D.	7.17E-05	N.D.	N.D.
Se	1.54E-05	6.12E-05	N.D.	N.D.	N.D.	4.12E-05	4.08E-05	3.99E-05	2.80E-05	N.D.
Br	3.32E-05	2.76E-04	1.01E-04	1.09E-04	7.91E-05	1.09E-04	3.23E-05	8.36E-05	1.25E-05	2.93E-05
Rb	3.01E-02	4.56E-02	7.06E-02	4.50E-02	8.77E-02	6.32E-02	3.43E-02	3.36E-02	1.17E-02	2.63E-02
Sr	2.67E-02	3.26E-01	5.05E-01	3.99E-02	7.77E-02	4.52E-01	3.04E-02	2.40E-01	8.38E-02	1.88E-01
Zr	2.87E-02	4.36E-02	6.74E-02	4.30E-02	8.37E-02	6.03E-02	3.28E-02	3.21E-02	1.12E-02	2.51E-02
Pb	3.95E-01	5.99E-01	9.27E-01	5.91E-01	1.15E+00	8.29E-01	4.51E-01	4.41E-01	1.54E-01	3.46E-01
Hg	1.07E-04	1.64E-04	5.19E-04	1.34E-04	3.97E-04	2.53E-04	1.92E-04	1.02E-05	5.01E-05	8.38E-05
W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cd	8.79E-04	6.93E-04	2.67E-03	7.66E-04	1.45E-02	1.23E-03	5.06E-04	2.08E-03	6.12E-05	3.41E-04
Sn	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sb	2.06E-05	6.66E-05	6.65E-05	5.34E-05	7.34E-05	3.75E-05	2.69E-05	2.80E-05	1.34E-05	2.98E-05
Ba	9.24E-03	1.40E-02	2.92E-01	1.38E-02	3.63E-01	2.61E-01	1.05E-02	1.03E-02	3.60E-03	8.09E-03
I	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Mg	2.11E-02	2.36E-02	1.99E-02	1.81E-02	4.25E-02	3.01E-02	1.84E-02	1.52E-02	7.91E-03	1.12E-02
Na	4.31E-04	1.20E-02	4.78E-03	5.50E-03	1.16E-03	9.14E-04	4.68E-04	4.02E-03	1.78E-04	2.65E-03
Sm	1.51E-06	1.31E-05	1.42E-05	4.50E-06	1.05E-05	8.17E-06	5.27E-06	4.43E-06	1.69E-06	4.99E-06
Ce	1.54E-05	1.67E-02	1.01E-04	9.29E-03	2.27E-04	8.26E-05	1.76E-05	8.12E-03	6.02E-06	1.35E-05
U	N.D.	N.D.	3.71E-05	N.D.	N.D.	N.D.	1.14E-05	N.D.	7.68E-06	8.64E-06
Th	9.83E-06	4.12E-05	5.89E-05	1.36E-05	1.50E-05	5.50E-06	2.37E-05	2.26E-05	6.47E-06	1.80E-05
La	5.23E-06	1.64E-05	4.49E-05	1.91E-05	2.25E-05	2.07E-05	1.25E-05	8.34E-06	4.02E-06	1.34E-05
Au	1.28E-06	N.D.	N.D.	1.25E-05	3.56E-06	2.29E-06	5.88E-06	N.D.	5.22E-07	9.97E-07
Ag	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	6.58E-06	N.D.	3.69E-06	N.D.
Sc	6.78E-06	1.31E-05	6.46E-06	5.68E-06	3.73E-06	3.48E-06	6.61E-06	8.08E-06	4.83E-06	5.67E-06
Eu	N.D.	2.50E-06	2.18E-06	2.25E-06	N.D.	N.D.	2.63E-06	N.D.	3.07E-07	N.D.
Cs	7.72E-06	1.17E-05	2.92E-05	1.16E-05	2.42E-05	1.87E-05	1.44E-05	8.62E-06	6.30E-06	9.71E-06
Mo	N.D.	4.43E-01	6.85E-01	4.37E-01	N.D.	6.13E-01	N.D.	3.26E-01	1.71E-01	2.55E-01
Lu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NA	1.34E-01	1.86E-01	2.60E-01	6.69E-02	3.91E-01	3.75E-01	2.16E-01	2.62E-01	2.18E-01	N.R.
N3	1.11E-02	3.00E-01	1.04E-01	8.34E-02	2.93E-01	7.05E-02	8.93E-02	7.50E-02	3.92E-02	N.R.
Ms	5.04E+00	1.10E+01	1.60E+01	1.27E+01	1.24E+01	6.10E+01	5.02E+01	1.69E+01	2.80E+01	4.38E+01
S4	1.41E-01	1.11E+00	4.03E-01	8.60E-02	9.00E-02	2.43E-01	2.33E-01	6.30E-01	5.73E-01	8.35E-01

All units are micrograms/M3 .
N.R. - Not Reported , and N.D. - Not Detected .

(continued)

TABLE D-3B (continued)

	36613	36614	36615	36616	36617	36618	36619	36621	36622	36623
Al	1.91E-03	1.48E-03	7.86E-03	5.83E-03	5.89E-03	1.08E-02	1.54E-03	1.78E-02	3.30E-02	1.90E-03
Si	1.26E-01	9.70E-02	3.22E-01	3.05E-01	2.29E-01	2.70E-01	1.39E-01	6.28E-01	1.93E-01	1.45E-01
P	5.74E-02	3.63E-03	1.20E-02	1.14E-02	8.56E-03	1.01E-02	5.21E-03	2.35E-02	7.22E-03	5.42E-03
S	3.23E-02	2.49E-02	8.28E-02	7.85E-02	5.89E-02	6.93E-02	3.58E-02	1.61E-01	4.97E-02	3.73E-02
Cl	9.34E-03	6.77E-03	1.01E-02	1.67E-02	1.13E-02	5.55E-03	8.20E-03	3.99E-02	1.26E-02	6.45E-03
K	7.18E-03	5.54E-03	1.84E-02	1.74E-02	1.31E-02	1.54E-02	7.96E-03	3.59E-02	1.10E-02	8.29E-03
Ca	7.18E-03	5.54E-03	1.84E-02	1.74E-02	1.31E-02	1.54E-02	7.96E-03	3.59E-02	1.10E-02	8.29E-03
Ti	3.59E-03	2.53E-03	9.20E-03	7.96E-03	5.98E-03	7.70E-03	3.98E-03	1.79E-02	5.52E-03	3.78E-03
V	8.34E-05	5.11E-05	8.31E-04	8.17E-05	2.61E-04	2.14E-04	1.67E-04	2.68E-04	1.09E-04	2.80E-04
Cr	4.36E-04	2.00E-04	1.38E-03	7.55E-04	2.78E-04	9.95E-04	1.28E-04	2.36E-03	7.24E-04	2.76E-04
Mn	1.51E-04	5.50E-05	4.69E-04	1.97E-04	1.77E-04	4.14E-04	7.44E-05	9.28E-04	3.78E-04	1.19E-04
Fe	5.22E-02	4.11E-02	1.36E-01	1.29E-01	9.71E-02	1.14E-01	5.90E-02	2.66E-01	8.19E-02	6.15E-02
Co	5.60E-06	2.13E-06	1.66E-05	7.07E-06	2.82E-06	8.94E-06	3.77E-06	4.59E-05	1.41E-05	1.59E-06
Ni	5.59E-03	4.75E-03	9.05E-03	1.15E-02	6.44E-03	6.78E-03	3.50E-03	2.94E-02	4.86E-03	3.86E-03
Cu	2.69E-02	2.08E-02	6.90E-02	6.54E-02	4.91E-02	5.78E-02	2.98E-02	1.35E-01	4.14E-02	3.11E-02
Zn	8.04E-04	1.00E-03	8.12E-03	2.42E-03	2.34E-03	1.78E-02	1.16E-03	9.09E-03	7.39E-03	1.27E-03
As	N.D.	N.D.	N.D.	N.D.	6.57E-05	5.50E-05	2.97E-05	N.D.	1.88E-04	N.D.
Se	3.86E-05	1.98E-05	4.40E-05	2.88E-05	6.04E-05	2.11E-04	2.54E-05	N.D.	4.54E-04	3.03E-05
Br	3.48E-04	3.09E-05	6.26E-05	1.02E-04	9.31E-05	1.07E-04	3.14E-05	1.44E-04	2.02E-04	1.66E-05
Rb	2.63E-02	2.03E-02	6.75E-02	6.39E-02	4.80E-02	5.65E-02	2.92E-02	1.32E-01	4.05E-02	3.04E-02
Sr	2.33E-02	1.80E-02	4.82E-01	4.57E-01	3.43E-01	4.04E-01	2.09E-01	1.17E-01	3.59E-02	2.69E-02
Zr	2.51E-02	1.94E-02	6.44E-02	6.10E-02	4.58E-02	5.39E-02	2.79E-02	1.26E-01	3.86E-02	2.90E-02
Pb	3.46E-01	6.79E-02	8.86E-01	8.39E-01	6.30E-01	7.42E-01	3.83E-01	1.73E+00	5.32E-01	3.99E-01
Hg	8.65E-05	7.74E-05	3.83E-04	8.46E-05	1.45E-05	1.75E-04	8.83E-06	1.00E-03	1.61E-04	6.48E-05
W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cd	3.88E-04	4.98E-04	5.49E-04	6.07E-04	1.41E-04	1.80E-03	2.50E-04	3.93E-04	1.10E-03	9.50E-05
Sn	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sb	4.88E-05	3.67E-05	1.70E-04	4.41E-05	3.99E-05	3.79E-05	1.94E-05	5.67E-04	2.45E-04	2.17E-05
Ba	1.09E-01	8.41E-02	2.07E-02	2.64E-01	1.98E-01	1.74E-02	1.21E-01	4.04E-02	1.67E-01	1.26E-01
I	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Mg	1.93E-02	8.78E-03	1.12E-01	1.92E-02	1.56E-02	1.74E-02	1.38E-03	1.65E-01	7.50E-02	3.34E-03
Na	7.71E-03	7.57E-03	9.07E-04	8.48E-04	4.04E-02	5.72E-03	1.30E-03	8.53E-03	2.91E-03	4.34E-04
Sm	1.01E-05	9.55E-07	7.78E-06	2.59E-06	2.97E-06	1.07E-05	1.45E-06	1.10E-04	8.84E-06	4.07E-07
Ce	9.29E-05	5.11E-05	3.46E-05	1.66E-04	5.53E-03	2.24E-02	2.12E-03	3.37E-03	4.27E-02	1.56E-05
U	1.88E-05	N.D.	4.14E-05	N.D.	7.10E-06	1.53E-05	6.52E-06	1.04E-04	3.97E-05	N.D.
Th	1.69E-05	2.51E-06	1.43E-04	2.59E-05	1.20E-05	7.95E-05	7.34E-06	3.06E-04	2.20E-05	1.20E-06
La	1.33E-05	4.57E-06	3.54E-05	1.33E-05	1.38E-05	1.85E-05	5.32E-06	1.16E-04	6.03E-05	4.09E-06
Au	N.D.	1.90E-07	1.15E-05	2.92E-06	N.D.	N.D.	N.D.	N.D.	N.D.	1.01E-06
Ag	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	4.66E-06
Sc	2.71E-06	1.94E-06	6.45E-05	1.38E-05	6.57E-06	2.37E-05	1.82E-06	1.05E-04	1.53E-05	1.66E-06
Eu	3.25E-06	7.14E-07	2.65E-06	N.D.	2.37E-06	N.D.	N.D.	3.12E-05	N.D.	N.D.
Cs	2.16E-05	5.21E-06	1.73E-05	2.44E-05	1.23E-05	1.45E-05	7.49E-06	1.31E-04	1.04E-05	1.31E-05
Mo	N.D.	1.97E-01	6.55E-01	6.20E-01	4.66E-01	5.48E-01	2.83E-01	1.28E+00	N.D.	N.D.
Lu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NA	2.54E-01	4.87E-01	4.26E-01	4.03E-01	9.03E-01	N.R.	1.62E-01	4.85E-02	1.01E-01	1.13E-01
N3	2.25E-01	3.02E-02	1.75E-01	4.71E-02	5.43E-02	6.29E-02	N.R.	9.70E-02	1.17E-01	1.13E-02
Ms	1.76E+01	3.78E+01	5.44E+01	1.23E+01	5.00E+01	1.11E+01	4.04E+00	7.97E+01	3.80E+01	3.54E+00
S4	4.13E-01	1.46E+00	1.89E+00	1.39E+00	1.74E+00	4.34E-01	3.93E-01	4.61E-01	3.33E-01	1.38E-01

* All units are micrograms/M3 .
N.R. - Not Reported , and N.D. - Not Detected .

(continued)

TABLE D-3B (continued)

	36636	36637	36638	36639	36640	36641	36644	36645	36646	36648
Al	4.10E-04	1.76E-03	2.61E-03	1.97E-03	7.01E-03	3.18E-03	3.41E-03	2.06E-03	5.54E-03	3.12E-03
Si	7.86E-02	7.85E-02	2.09E-01	7.60E-03	3.49E-01	1.84E-01	1.79E-01	2.04E-01	1.14E-01	1.36E-02
P	2.94E-03	3.59E-02	7.80E-03	8.12E-03	1.31E-02	6.87E-03	6.70E-03	7.63E-03	4.27E-03	1.45E-02
S	2.02E-02	2.02E-02	5.36E-02	5.58E-02	8.99E-02	4.73E-02	4.61E-02	5.25E-02	2.94E-02	9.99E-02
Cl	5.13E-03	3.01E-03	1.44E-02	1.14E-02	2.29E-02	9.18E-03	1.69E-02	9.00E-03	5.83E-03	1.42E-02
K	4.49E-03	4.49E-03	1.19E-02	1.24E-02	2.00E-02	1.05E-02	1.02E-02	1.17E-02	6.52E-03	2.22E-02
Ca	4.49E-03	4.49E-03	1.19E-02	9.82E-03	2.00E-02	1.05E-02	1.02E-02	9.24E-03	6.52E-03	1.76E-02
Ti	2.25E-03	2.05E-03	5.44E-03	5.67E-03	9.98E-03	4.80E-03	5.12E-03	5.83E-03	3.26E-03	1.01E-02
V	1.05E-04	1.20E-04	1.41E-04	1.17E-04	4.10E-05	1.18E-04	3.69E-05	2.45E-05	2.51E-04	2.24E-05
Cr	1.19E-04	1.59E-04	4.92E-04	3.56E-04	9.40E-04	4.80E-04	4.34E-04	3.99E-04	8.87E-04	7.54E-04
Mn	7.78E-05	8.13E-05	1.43E-04	1.14E-04	1.68E-04	6.63E-05	6.63E-05	5.70E-05	1.81E-04	1.30E-04
Fe	3.33E-02	3.33E-02	4.56E-02	4.75E-02	1.48E-01	7.79E-02	7.60E-02	8.66E-02	4.84E-02	8.49E-02
Co	1.44E-06	1.83E-06	4.55E-06	3.33E-06	7.52E-06	4.11E-06	5.21E-06	3.12E-06	3.67E-06	6.44E-06
Ni	1.98E-03	2.88E-03	9.00E-03	1.11E-02	1.71E-02	7.58E-03	5.94E-03	7.35E-03	2.87E-03	1.64E-02
Cu	1.68E-02	1.68E-02	4.47E-02	4.65E-02	7.49E-02	3.94E-02	3.84E-02	4.38E-02	2.45E-02	8.32E-02
Zn	1.52E-03	1.32E-03	1.08E-03	1.48E-03	2.11E-03	1.60E-03	1.27E-03	7.33E-04	2.66E-03	1.42E-03
As	N.D.	3.49E-05	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Se	3.25E-05	3.23E-05	1.84E-05	6.52E-05	2.16E-05	1.53E-05	1.64E-05	1.98E-05	8.21E-06	4.58E-05
Br	6.42E-05	5.30E-05	3.26E-05	2.72E-05	6.19E-04	1.30E-04	7.71E-05	1.10E-04	4.46E-05	2.09E-04
Rb	1.65E-02	1.65E-02	4.37E-02	4.55E-02	7.32E-02	3.85E-02	3.76E-02	4.28E-02	2.39E-02	8.14E-02
Sr	1.18E-01	1.18E-01	3.12E-01	3.25E-01	5.23E-01	3.41E-02	3.33E-02	3.79E-02	2.12E-02	7.21E-02
Zr	1.57E-02	1.57E-02	4.17E-02	4.34E-02	6.99E-02	3.68E-02	3.59E-02	4.08E-02	2.28E-02	7.77E-02
Pb	2.16E-01	2.16E-01	5.74E-01	5.97E-01	9.61E-01	5.06E-01	4.93E-01	5.62E-01	3.14E-01	1.07E+00
Hs	4.40E-05	4.98E-06	1.82E-04	1.54E-04	3.32E-04	9.85E-05	1.63E-04	2.21E-04	1.99E-04	3.06E-04
W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cd	6.00E-05	1.87E-03	3.34E-04	2.43E-04	1.06E-03	1.37E-03	1.15E-03	4.49E-04	1.42E-04	6.50E-04
Sn	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sb	2.58E-05	3.67E-05	6.14E-05	2.43E-05	5.58E-05	5.48E-05	2.67E-05	2.42E-05	2.05E-05	3.97E-05
Ba	5.06E-03	6.81E-02	1.81E-01	1.88E-01	3.03E-01	1.18E-02	1.15E-02	1.31E-02	7.35E-03	2.50E-02
I	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Ms	8.60E-03	7.09E-03	2.06E-03	1.34E-02	2.89E-02	8.83E-03	6.49E-03	3.29E-03	1.40E-02	3.84E-03
Na	3.72E-03	4.11E-03	3.38E-03	2.70E-03	3.51E-03	4.96E-03	5.01E-04	7.72E-04	3.17E-04	1.33E-03
Sm	8.81E-07	1.01E-06	1.20E-06	6.09E-07	1.24E-05	1.90E-06	3.81E-06	1.10E-06	5.33E-06	1.39E-05
Ce	2.73E-03	2.06E-03	2.24E-05	2.34E-05	1.26E-04	4.10E-05	7.20E-05	5.57E-05	1.08E-04	3.54E-04
U	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.41E-05	8.15E-06	N.D.
Th	2.72E-06	3.69E-06	1.73E-06	1.80E-06	2.31E-05	3.22E-06	4.08E-06	2.75E-06	1.38E-05	6.61E-05
La	3.55E-06	8.17E-06	1.10E-05	6.34E-06	4.88E-05	1.57E-05	1.63E-05	2.13E-05	2.79E-05	7.58E-05
Au	N.D.	N.D.	N.D.	N.D.	8.97E-06	1.13E-06	9.51E-07	N.D.	6.89E-07	N.D.
As	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	4.70E-06	N.D.
Sc	2.13E-06	2.28E-06	1.45E-06	2.48E-06	3.53E-06	2.02E-06	1.19E-06	2.32E-06	1.21E-06	1.87E-06
Eu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cs	4.23E-06	4.22E-06	4.77E-05	1.53E-05	3.34E-05	1.97E-05	1.23E-05	1.51E-05	7.97E-06	2.63E-05
Mo	1.60E-01	1.60E-01	4.24E-01	4.42E-01	7.11E-01	N.D.	N.D.	N.D.	2.32E-01	7.90E-01
Lu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NA	8.58E-02	4.38E-01	1.17E-01	1.18E-01	1.90E-01	1.22E-01	8.72E-02	9.54E-02	2.04E-01	3.32E-01
N3	2.45E-02	1.22E-02	1.17E-01	2.52E-02	2.70E-02	4.02E-02	N.R.	1.58E-02	8.85E-03	N.R.
Ms	5.60E+00	4.90E+00	7.72E+00	4.78E+00	5.10E+00	3.44E+01	6.36E+00	5.42E+00	1.18E+01	5.42E+00
S4	6.62E-01	8.13E-01	5.41E-01	6.88E-01	3.53E-01	4.48E-01	4.98E-01	5.12E-01	5.50E-01	6.55E-01

* All units are microsrams/M3 .
N.R. - Not Reported , and N.D. - Not Detected .